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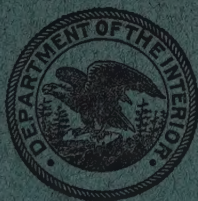
BULLETIN 788

*Leland K. Denzel*  
TOPOGRAPHIC INSTRUCTIONS

OF THE

UNITED STATES GEOLOGICAL SURVEY

C. H. BIRDSEYE  
Chief Topographic Engineer



UNITED STATES  
GOVERNMENT PRINTING OFFICE  
WASHINGTON  
1928





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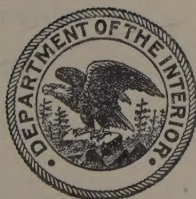
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## PREFACE

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This manual is intended to replace all former instructions relating to the topographic work of the United States Geological Survey and to provide a manual of instruction for the personnel of other organizations engaged in topographic surveying. An attempt has been made to have these instructions complete so far as the technical work of topographic mapping is concerned. General regulations and instructions for the Geological Survey have for the most part been omitted, but those relating to fiscal affairs and to a few other important phases of administration have been digested and repeated herein.

The manual is issued in several parts, each covering a general subject, thus saving public funds by providing a distribution of separate parts to those interested only in one or more of the subjects. These several parts have been prepared by the members of the topographic branch best qualified for each task, and each part has been reviewed and revised by the section chief responsible for the administration of that particular part of topographic work.

Each part, except "Administration," has been approved by the Board of Surveys and Maps. In fact, all the technical parts have been reviewed by a committee of the board and made a part of a report of that committee.

Criticism of these instructions, suggestions for their improvement, and notice of errors or omissions are invited.

C. H. BIRDSEYE,  
*Chief Topographic Engineer.*

Approved:

GEO. OTIS SMITH, *Director.*

WASHINGTON, D. C., June 7, 1926.





# TOPOGRAPHIC INSTRUCTIONS OF THE UNITED STATES GEOLOGICAL SURVEY

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## A. ADMINISTRATION

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Compiled by H. M. FRYE

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### AUTHORIZATION FOR TOPOGRAPHIC WORK

The United States Geological Survey was created by act of Congress approved March 3, 1879, and the formation of the topographic branch was the natural result of the growth of the organization. It was apparent from the beginning that no adequate classification of lands or conclusive geologic determinations could be made without base maps. Hence in the earlier years the topographic maps were made as a part of the general work of the Geological Survey, and allotments for the cost of such maps were made from the general appropriation.

### APPROPRIATION ACTS

The sundry civil act for the fiscal year 1889 appropriated funds for one chief geographer, three geographers, and three topographers. These positions were provided for until the end of the fiscal year 1892. For the fiscal years 1893 to 1924 one chief geographer, one geographer, and two topographers were specifically provided for under the heading "Scientific assistants," except that for the fiscal years 1897 to 1924 the title "chief" was omitted. Beginning with the fiscal year 1923 appropriations for the topographic work have been made in the Interior Department appropriation act. For the fiscal years 1925-1927 the compensations of "scientific assistants" were not itemized but were included in a lump sum.

A specific appropriation for topographic surveys was first made in the sundry civil act of October 2, 1888, for the fiscal year 1889.

Below are quotations from the sundry civil and Interior Department appropriation acts for several years, showing the principal

changes in the wording of the acts; the intervening acts contain changes only in amounts appropriated or slight changes in the wording of the authorizations.

*Fiscal year 1889.*—For topographic surveys in various portions of the United States, including the pay of temporary employees in field and in office, the cost of all instruments, apparatus, and materials, and all other necessary expenses connected therewith, \$199,000.

*Fiscal year 1891.*—For topographic surveys in various portions of the United States, \$325,000, one-half of which sum shall be expended west of the one hundredth meridian.

*Fiscal year 1893.*—For topographic surveys in various portions of the United States, \$240,000; \$60,000 of which shall be expended west of the ninety-seventh meridian in the States of North Dakota, South Dakota, Nebraska, Kansas,<sup>1</sup> and the Territory of Oklahoma, and at least one-half of the remainder shall be expended west of the one hundred and third meridian.

*Fiscal year 1897.*—For topographic surveys in various portions of the United States, \$175,000, to be immediately available, \$35,000 of which shall be expended west of the ninety-seventh meridian in the States of North Dakota, South Dakota, Nebraska, Kansas, Texas, and the Territory of Oklahoma, and at least one-third of the remainder shall be expended west of the one hundred and third meridian: *Provided*, That hereafter in such surveys west of the ninety-fifth meridian elevations above a base level located in each area under survey shall be determined and marked on the ground by iron or stone posts or permanent bench marks, at least two such posts or bench marks to be established in each township or equivalent area, except in the forest-clad and mountain areas, where at least one shall be established, and these shall be placed, whenever practicable, near the township corners of the public-land surveys; and in the areas east of the ninety-fifth meridian at least one such post or bench mark shall be similarly established in each area equivalent to the area of a township of the public-land surveys.

*Fiscal year 1898.*—For the survey of the public lands that have been or may hereafter be designated as forest reserves by Executive proclamation, \* \* \* and including public lands adjacent thereto, which may be designated for survey by the Secretary of the Interior, \$150,000, to be immediately available: \* \* \* The surveys herein provided for shall be made under the supervision of the Director of the Geological Survey, \* \* \* and if subdivision surveys shall be found to be necessary, they shall be executed under the rectangular system, as now provided by law. The plats and field notes prepared shall be approved and certified to by the Director of the Geological Survey, and two copies of the field notes shall be returned; \* \* \* and twenty photolithographic copies of the plat shall be returned, \* \* \* the original plat and other copies \* \* \* shall have the facsimile signature of the Director of the Survey attached. \* \* \* *Provided, however*, That a copy of every topographic map and other maps showing the distribution of the forests, together with such field notes as may be taken relating thereto, shall be certified thereto by the Director of the Survey and filed in the General Land Office.

*Fiscal year 1900.*—For topographic surveys in various portions of the United States, \$240,000, to be immediately available;<sup>2</sup>

<sup>1</sup> In subsequent years Texas was included.

<sup>2</sup> For 1913 and 1916 the words "to be immediately available" were eliminated, and for 1914 and 1915 the words "one-half to be immediately available" were included.



For continuation of the survey<sup>3</sup> of the public lands that have been or may hereafter be designated as forest reserves,<sup>4</sup> \$130,000, to be immediately available.<sup>2</sup>

*And provided further,* That hereafter all standard, meander, township, and section lines of the public-land surveys shall, as heretofore, be established under the direction and supervision of the Commissioner of the General Land Office, whether the lands to be surveyed are within or without reservations, except that where the exterior boundaries of public forest reservations are required to be coincident with standard, township, or section lines such boundaries may, if not previously established in the ordinary course of the public-land surveys, be established and marked under the supervision of the Director of the United States Geological Survey whenever necessary to complete the survey of such exterior boundaries.

*Fiscal year 1917.*—For topographic surveys in various portions of the United States, \$350,000: *Provided,* That in expending this sum preference shall be given special topographic surveys of areas selected by the War Department and in securing such extra topographic data as are requested by the War Department in these or other areas;

For continuation of topographic surveys of the public lands that have been or may hereafter be designated as national forests, \$75,000.

*Fiscal year 1920.*—For topographic surveys in various portions of the United States, including lands in national forests, \$325,000.

*Fiscal year 1924.*—For topographic surveys in various portions of the United States, including lands in national forests, \$500,000: *Provided,* That no part of this appropriation shall be expended in cooperation with States or municipalities except upon the basis of the State or municipality bearing all of the expense incident thereto in excess of such an amount as is necessary for the Geological Survey to perform its share of standard topographic surveys.

*Fiscal year 1926.*—For topographic surveys in various portions of the United States, including lands in national forests, \$485,000, of which amount not to exceed \$305,900 may be expended for personal services in the District of Columbia: *Provided,* That no part of this appropriation shall be expended in cooperation with States or municipalities except upon the basis of the State or municipality bearing all of the expense incident thereto in excess of such an amount as is necessary for the Geological Survey to perform its share of standard topographic surveys.

*Fiscal year 1927.*—For topographic surveys in various portions of the United States, including lands in national forests, \$451,700, of which amount not to exceed \$267,000 may be expended for personal services in the District of Columbia: *Provided,* That no part of this appropriation shall be expended in cooperation with States or municipalities except upon the basis of the State or municipality bearing all of the expense incident thereto in excess of such an amount as is necessary for the Geological Survey to perform its share of standard topographic surveys, such share of the Geological Survey in no case exceeding 50 per cent: *Provided further,* That \$372,200 of this amount shall be available only for such cooperation with States or municipalities.

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<sup>2</sup> See footnote 2, p. 2.

<sup>3</sup> For 1909 and subsequent years this wording was changed to "topographic survey."

<sup>4</sup> For 1910 and subsequent years this wording was changed to "national forests."

## DEFICIENCY ACTS

The Geological Survey has had only two deficiency appropriations for topographic surveys. The deficiency act of July 28, 1892, carried the following appropriation:

Geological Survey: For topography east of one hundredth meridian, fiscal year 1891, \$3,818.87; for topography west of one hundredth meridian, fiscal year 1891, \$754.51----- \$4, 573. 38

The first deficiency act for the fiscal year 1926, approved March 3, 1926, contained the following provision:

*United States Geological Survey.*—For topographic surveys in various portions of the United States, including the general objects of expenditure enumerated in the second paragraph under the caption "United States Geological Survey," in the Interior Department appropriation act for the fiscal year 1926, and including not to exceed \$33,000 for personal services in the District of Columbia, fiscal year 1926, \$73,300, to be expended in cooperation with States or municipalities on standard topographic surveys and on a basis on which the share of the Geological Survey shall in no case exceed 50 per cent.

## TEMPLE ACT

Since the war engineers and others have demanded more rapid progress in the completion of the standard topographic map. This interest resulted in the passage by the Sixty-eighth Congress of what is known as the Temple Act, approved February 27, 1925, which is as follows:

AN ACT To provide for the completion of the topographical survey of the United States.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the President be, and hereby is, authorized to complete, within a period of twenty years from the date of the passage of this act, a general utility topographical survey of the territory of the United States, including adequate horizontal and vertical control, and the securing of such topographic and hydrographic data as may be required for this purpose, and the preparation and publication of the resulting maps and data: *Provided,* That in carrying out the provisions of this act the President is authorized to utilize the services and facilities or such agencies of the Government as now exist or may hereafter be created, and to allot to them (in addition to and not in substitution for other funds available to such agencies under other appropriations or from other sources) funds from the appropriation herein authorized, or from such appropriation or appropriations as may hereafter be made for the purpose of this act.

SEC. 2. That the agencies which may be engaged in carrying out the provisions of this act are authorized to enter into cooperative agreements with and to receive funds made available by any State or civic subdivision for the purpose of expediting the completion of the mapping within its borders.

SEC. 3. The sum of \$950,000 is hereby authorized to be appropriated out of any moneys in the Treasury not otherwise appropriated, to be available until the 30th day of June, 1926, for the purpose of carrying out the provisions of this act, both in the District of Columbia and elsewhere as the President may deem essential and proper.



## COOPERATION WITH WAR DEPARTMENT ON SPECIAL MILITARY INFORMATION

*First agreement.*—On January 12, 1905, an agreement was approved by the Secretary of the Interior and the Secretary of War designed to make the topographic maps of the Geological Survey more useful to the War Department. This agreement provided that the Geological Survey should show on its topographic maps resulting from new surveys or resurveys the location and extent of timbered areas, of important railroad cuts and embankments, and of important arroyos, and should furnish to the War Department one photolithographic copy of each new topographic map on which the following special military information should be lettered by appropriate and authorized abbreviations: Whether streams are fordable or unfordable; the width, depth of water, character of bottom, and height and steepness of banks of all unfordable streams at points of crossing; the length, kind, character of material, and height above water of wagon and railroad bridges over the unfordable streams; the location of the highest points of hills and ridges; the nature of ferries; and the location of mills, waterworks, and roundhouses.

*Second agreement.*—The photolithographic maps furnished under the first agreement did not prove satisfactory to the War Department, and on October 14, 1911, a second agreement was approved by the Secretary of the Interior and the Secretary of War, which provided that the Geological Survey should issue a special War Department edition of 100 copies of each topographic map published on a scale of 1:62,500 or larger, on which should be printed the special military information previously requested, together with the location of blacksmith shops, permanent post-office buildings, churches, and schoolhouses.

The agreement also provided that the Geological Survey should concentrate its topographic mapping efforts on those unmapped areas of the United States along the coasts and borders, and should comply, so far as practicable, with requests made by the War Department to give priority to work in areas of which maps were needed for military purposes. The War Department agreed to obtain annual appropriations of about \$60,000 to reimburse the Geological Survey for this additional work, but the first of these appropriations was not approved until July 1, 1916, and was carried in the sundry civil act for 1917, as follows:

*Topographic maps, War Department.*—For reimbursing the United States Geological Survey for expenses incurred in making special topographic surveys of areas selected by the War Department, and for additional expenses incurred in securing such extra topographic data as are requested by the War Department in these or other areas, and engraving and printing the same on atlas sheets of the United States Geological Survey, \$35,000: *Provided, That*

the Secretary of War is authorized to advance from this appropriation to the United States Geological Survey such sums as the Secretary of the Interior may request.

This agreement remained in effect until after the end of the World War, and the Geological Survey delivered to the War Department special military editions of its topographic maps, each accompanied by a confidential report containing military information.

During the World War the topographic branch of the Geological Survey gave its entire attention to special military surveys, and the importance of topographic mapping was emphasized as a matter of vital military necessity.

Since 1917 appropriations have been made in War Department acts under the heading "Military surveys and maps," and funds have been allotted from such appropriations to repay the Geological Survey for topographic surveys requested by the War Department.

*Third agreement.*—In 1920 the War Department adopted the standard topographic maps of the Geological Survey as the tactical maps for the use of the Army, and a third agreement between the Secretary of the Interior and the Secretary of War canceled the former agreements and authorized the abandonment of the collection by the Geological Survey of confidential military information.

This agreement provided that the Geological Survey should show on its standard topographic maps a classification of highways and highway bridges and the rectangular grid adopted by the Army and should furnish to the War Department 200 copies of each standard topographic map published thereafter.

The agreement also provided that the War Department would, except in emergency, cease publication of progressive military or tactical maps of areas mapped by the Geological Survey, and would concentrate its topographic mapping in the continental United States to special military surveys, to quadrangle mapping of areas not mapped by the Geological Survey, and to the revision of old maps.

The agreement further provided that the War Department would allot to the Geological Survey not less than 50 per cent annually of its appropriation for military surveys and maps, to be expended on topographic surveys of such areas as were mutually agreed upon.

*Fourth agreement.*—In 1926 a fourth agreement was approved by the Secretary of the Interior and the Secretary of War replacing all former agreements. This agreement embodied the principal features of the third agreement with the following exceptions: Provision was made that the Geological Survey would furnish the War Department with 300 instead of 200 copies of each standard topographic map published by the Geological Survey, credit to be applied to the War Department's quota for the number of copies not delivered and all requests for maps to be made through the Chief of Engineers.



The agreement provided that the Corps of Engineers would allot to the Geological Survey not less than \$12,500 annually from its appropriation for military surveys and maps.

Provision was also made to add the Harriman index number of the quadrangle to each topographic map if the use of that system is approved by the Board of Surveys and Maps.

The following is an extract from the War Department appropriation act of 1927:

*Military surveys and maps.*—For the execution of topographic and other surveys, the securing of such extra topographic data as may be required, and the preparation and printing of maps required for military purposes and for research and development of surveying by means of aerial photography and in field reproduction methods, to be immediately available and remain available until December 31, 1927, \$80,000:<sup>5</sup> *Provided*, That the Secretary of War is authorized to secure the assistance, wherever practicable, of the United States Geological Survey, the Coast and Geodetic Survey, or other mapping agencies of the Government in this work and to allot funds therefor to them from this appropriation.

### STATE COOPERATION

In addition to funds appropriated direct to the Geological Survey and allotments made by the War Department, the Geological Survey has, since the fiscal year 1885, engaged in cooperation with many States and their subdivisions, the States paying part (usually half) of the expense of topographic mapping. For the fiscal year 1927 the several States have allotted \$378,791.88.

On page 36 is a table showing by fiscal years the funds made available for topographic mapping from all sources, and on pages 29–35 detailed information in regard to such cooperation.

### ORGANIZATION OF THE TOPOGRAPHIC BRANCH

The topographic branch is organized under the direction of a chief topographic engineer into three field divisions (Atlantic, Central, and Pacific), each of which is in charge of a division engineer.

The Atlantic division is subdivided into the New England, Middle Atlantic, South Atlantic, and Ohio Valley sections; the Central division into the Great Lakes, Missouri Valley, Red River, and Rocky Mountain sections; and the Pacific division into the North Pacific, South Pacific, Salt Lake Basin, and Hawaiian sections. Each section is in charge of a topographic engineer.

The office work is both administrative and technical in character.

The administrative work is handled by a chief clerk allocated to clerical, administrative, and fiscal service, grade 7, assisted by clerical employees ranging from grades 5 to 2.

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<sup>5</sup> Of this amount \$12,500 was allotted to the Geological Survey.

Technical office work is divided into five sections—computing, inspection and editing, cartography, photographic surveying, and relief mapping—and each section is in charge of a topographic engineer in professional and scientific service, grade 4, or an associate engineer in professional and scientific service, grade 3. The personnel of each of these sections is made up of professional, subprofessional, and clerical employees of various grades.

The members of the technical force, with headquarters at Washington, D. C., and those with headquarters in the field, are classified in professional, subprofessional, and field grades as follows:

	District of Columbia classification	Field classification	Range of salaries
Chief topographic engineer.....	P. and S.-5.....	.....	\$5,200-\$6,000
Division engineers.....	P. and S.-5.....	F.-16.....	5,200- 6,000
Topographic engineers in charge.....	P. and S.-4.....	F.-16.....	3,800- 5,000
Associate engineers.....	P. and S.-3.....	F.-13.....	3,000- 3,600
Assistant engineers.....	P. and S.-2 or S. P.-8.....	F.-11.....	2,400- 3,000
Chief engineering aids.....		.....	.....
Junior engineers.....	P. and S.-1 or S. P.-6.....	F.-9.....	1,860- 2,400
Senior engineering aids.....	S. P.-4.....	F.-7.....	1,500- 1,860
Assistant engineering aids.....	S. P.-2.....	F.-5.....	1,140- 1,500
Apprentice engineering aids.....	.....	.....	.....

Promotions within the grades are made by the Department of the Interior on the basis of efficiency ratings, but reallocations to fill vacancies in a different grade require the approval of the Personnel Classification Board.

Entrance into the engineering aid group has been made through certification by the Civil Service Commission after the applicant passed an examination for topographic aid. No examination for this position has been held since 1924, and no new appointments in the engineering aid groups are contemplated. Those who entered the service through the examination for topographic aid in 1924 are not eligible for promotion above \$1,800 without qualifying for the professional service.

Entrance into the professional grade is made through certification by the Civil Service Commission after the applicant has passed the technical examination for junior topographic engineer. This examination is usually held yearly, during the college spring-vacation period, and one of the necessary requirements is a degree in civil engineering from an institution of recognized standing. Engineers with the proper qualifications and civil-service status may be transferred to the professional grade from other departments, providing there are vacancies.

### PUBLICATIONS

The published results of the work of the topographic branch are maps and geodetic reports. The office work consists principally of



computing and adjusting field observations, inking and drafting field sheets, and inspecting and editing maps for final publication. The engraving and printing of these maps is done by the division of engraving and printing, another unit of the Geological Survey.

### GENERAL OFFICE INSTRUCTIONS

*Travel authorization.*—Every permanent man must have a travel authorization before leaving for the field, the number and date of which must be shown on all vouchers claiming expenses for travel or per diem.

*Letters of instruction.*—At the beginning of the field season and at the completion of an assignment, letters of instruction are issued to permanent men in regard to their field work. Authority for purchases or repairs exceeding \$100, for the employment or promotion of temporary assistants, and for the delivery of camp outfits, animals, or automobiles is also given when necessary.

*Miscellaneous instructions.*—Before leaving the Washington office for an assignment, field men should turn in all office instruments and map material, clear their desks and map file cases, submit a report of their office work, send address cards to the new post offices, and report to their division engineers that they have carried out these instructions.

### ORGANIZATION OF FIELD PARTIES

#### CLASSIFICATION

The chief topographic engineer is responsible for the administrative and technical control of all the work of the topographic branch, acting under the general supervision of the Director.

The division engineers are responsible for all the technical and administrative work of their respective divisions, acting under the general supervision of the chief topographic engineer.

Topographic engineers in charge of sections exercise such specific technical and administrative control over the employees of the section as may be delegated to them by the division engineer. The technical supervision is usually close and specific; the administrative supervision is more general.

The party chiefs are usually in the grade of associate engineer, and they exercise immediate supervision over the members of their parties under the general or specific instructions of the section and division chiefs. Under some conditions engineers of lower grades act as party chiefs, but usually the sequence of work and authority is graded down to the lowest engineering aid, and the entire field party, in charge of an associate engineer, is made up of one or more employees of each lower grade. Recorders, rodmen, chainmen, packers, teamsters, chauffeurs, and cooks are in the unclassified service and are employed as temporary assistants.

## EMPLOYMENT OF TEMPORARY ASSISTANTS

*Applications.*—Persons desiring temporary employment as rodmen, recorders, chainmen, etc. (grade 1), must file applications, on the form provided for that purpose, with the chief topographic engineer in Washington. Appointments will be made by the section or party chiefs from the list of applicants on file as vacancies occur in field parties, preference being given to former employees of the Survey whose services have been satisfactory and who are endeavoring to prepare themselves for civil-service examination for the grade of junior topographic engineer; to applicants who are available for the entire field season (usually April 15 to November 15); to residents of States in which service is to be performed; to other applicants in order of priority of application and fitness for the work.

Applicants for grade 1 must be free from all contagious diseases and qualified for rigorous outdoor work and must be between the ages of 20 and 40 years. The rate of pay for initial employment is \$110 to \$120 a month, the employee paying his own subsistence expenses and his traveling expenses to and from the place of employment.

Laborers, chauffeurs, teamsters, packers, and cooks (grade 2) are employed by the party chiefs as the necessity may arise.

*Letters of employment.*—Before entering upon his field duties every temporary employee must sign an agreement specifying the terms of his employment, and the party chief must forward this letter of employment immediately to the section chief or division engineer for approval and transmittal to the chief topographic engineer. Salaries for more than one week's services can not be paid until letters of employment are on file. Temporary employees hired in connection with their automobiles should sign letters of employment. Application cards should be made out by temporary employees hired in the field and should be submitted with their letters of employment.

## FIELD ADMINISTRATION

*Field insurance.*—As no leave of absence is given to temporary employees in the field, whether employed by the month or by the day, their pay stops immediately if they become incapacitated by reason of accident or sickness. In order that other members of a party may not be called on to bear the expenses entailed by sickness or accident of one member, chiefs of parties are instructed to urge all employees to take out insurance. To provide this insurance at the lowest possible rate a mutual-benefit association has been formed by members of the Geological Survey and other Government bureaus. This association exists solely for the purpose of giving health and accident insurance to field men at cost and of preventing unnecessary burdens



from falling on the immediate associates of those disabled. Information concerning membership may be obtained from chiefs of parties.

*Right to compensation for personal injuries.*—Under the Federal compensation act of September 7, 1916, all civil employees of the United States are entitled to compensation for injuries sustained in the performance of duty which cause disability to perform work for a period of more than three days. The act also provides for the payment of certain expenses incurred for medical and hospital attention resulting from such injuries.

The act provides no benefits for sickness not due to injuries, but an amendment, approved June 6, 1924, provides that compensation shall be paid for occupational diseases or "any disease proximately caused by the employment."

The mere fact that disease develops after the employee enters Government service can not be accepted as sufficient basis for an award of compensation; direct causal relationship of the employment must be shown, and common diseases, such as colds, pneumonia, tuberculosis, typhoid fever, or rheumatism, which may be and usually are due to causes entirely outside the employment, can rarely and only under the most unusual conditions be the basis of an award under this act.

Section 20 of the compensation act provides that original claims for compensation for disability shall be made within 60 days after the injury, but for any reasonable cause the commission may allow such claims to be made at any time within one year. All original claims for compensation for death shall be made within one year after death.

Chiefs of parties should provide themselves with a copy of "Regulations concerning duties of employees, official supervisors, medical officers, and others," a printed list showing the location of all designated medical officers, hospitals, and dispensaries, and blank forms for reporting injuries and filing claims for compensation in compliance with the regulations.

In case an employee is injured in a section of the country where no United States medical officer or hospital is located, and there is no physician designated for that vicinity in the printed list issued by the commission, a local physician may be employed. (See the regulations above cited, p. 36, pars. 93-98.)

The chief topographic engineer should be notified immediately in regard to every injury resulting in death, or in any loss of time, or in any expenditure for medical, surgical, or hospital services or supplies. These reports should not be omitted in cases in which the time lost was covered by annual or sick leave or in which no claim for compensation is contemplated.

The blanks covering the employee's injury and claim for expenses should be properly filled out in the field and forwarded to the chief topographic engineer for transmittal to the Employees' Compensation Commission.

*Typhoid-fever prevention.*—Field men are more liable to contract typhoid fever than any other disease. It is therefore urged that everyone who has not already had that disease protect himself against it by inoculation with any antityphoid serum or "vaccine" as prepared and administered by the United States Army surgeons. This prophylactic will be administered without charge to anyone applying in person to the designated officers of the Public Health Service in each State. (See Treasury Department Circular, Public Health Service, November 24, 1922.)

Farmers' Bulletin 478, United States Department of Agriculture, gives valuable suggestions on means of avoiding typhoid fever and the use of the prophylactic for its prevention.

*Care of public property.*—Chiefs of parties will be held responsible for the public property intrusted to their care and are expected to see that it receives no rougher usage than conditions necessitate.

*Purchase of property in field.*—Every article of property which appears on a voucher as having been purchased and which is not expendable must be accounted for on the returns to the custodian. In cooperating States separate Federal vouchers for such articles must be submitted for payment. Those in direct charge of property should be prepared to make a statement to the custodian as to its condition and the amount on hand. Animals, tents, wagons, and property of considerable value must not be purchased without authority from the division engineer. Animals purchased must be reported on Form 9-061.

*Storage.*—In arranging for the care of field property at the end of a season efforts should be made to store it near a main line of railway; if possible, in a fireproof building.

*Contracts for storage, etc.*—If the total storage charge estimated for the winter season will not exceed \$100, it is only necessary to have a record of the transaction that will place some obligation on the caretaker. Three copies of "Receipt, proposal, and acceptance," for storage or pasturage (Form 9-007 or 9-008) must therefore be prepared, one copy to be delivered to the caretaker and two to be sent to the chief topographic engineer through the division engineer.

The following requirements must be observed if the total charge for storage, or the other services indicated, will exceed \$100:

1. A contract must be entered into for continuing services such as pasturage and storage, hire of team or automobile not employed in connection with services of individual, hire of horses, hire of



room for office or storage, and all other continuing services other than personal when the total payments for the fiscal year will exceed \$100. Field men must determine whether or not the payments will run above this figure and act accordingly.

2. If it is found that a contract will be necessary, bids for the service must be obtained from three or more dealers if possible; the lowest bid is to be accepted if satisfactory, and a contract entered into. The contract must be sent to the Washington office for approval. If the lowest bid is not accepted, a detailed statement of the reasons for accepting a higher bid must accompany the contract.

3. The short-form contract should be submitted in quadruplicate, two copies to be signed by the contractor and a third to bear the "Oath of disinterestedness." After approval, one of the signed copies will be returned to the contractor by the Washington office.

4. If no competition is available and a contract is necessary, it may be entered into with the only available dealer, but a statement to that effect should accompany it, and each voucher covering payment for the service should indicate by the symbols "4(c)" that there was only one contractor from whom the service could be obtained, and by "A" under "Form of agreement" that a contract has been entered into.

5. Day-to-day purchases of oil and gasoline and repairs to automobiles are not continuing services, and therefore the only limitation to such transactions is that no daily purchase or repair bill may exceed \$100 without a formal contract. Vouchers must not be split in order to avoid the necessity of entering into a formal contract.

All contracts for continuing service, except personal employment, should be renewed at the beginning of the fiscal year.

Prior authority should be procured from the chief topographic engineer for all expenditures in excess of \$100 and from the Director for all in excess of \$500.

*Inventories.*—When nonexpendable property is stored a detailed inventory (Form 9-054) stating the condition of each article must be made and forwarded to the chief topographic engineer. Reports on condition and transfer of automobiles and of livestock should be made at the same time. When property, automobiles, or animals are removed from storage or pasturage, inventories and proper reports should be made in triplicate, one copy to be retained by the field man, one copy to be delivered to the caretaker, and one copy to be mailed to the branch chief clerk for transmission to the division of field equipment. At the end of a field season an inventory on Form 9-445-b must be made of all property charged against the party chief by the division of field equipment since the beginning of the year that has not been previously reported on this form. All prop-

erty that is being returned, held, transferred, or stored or that has been lost should be included.

*Transfer of property.*—When equipment is transferred from one field man to another an inventory of property (Form 9-054) should be made out; for automobiles Form 9-057 should be used, and for livestock Form 9-061. Instruments and other property should be recorded on Forms 9-139 and 9-455-b. All these reports should be transmitted to the branch chief clerk.

*Sale of property.*—Survey property can be sold only at public auction (see instructions in par. 74, fiscal regulations); an inspection report on Form 9-047 and authorization from the Director are required before the sale is held. When so authorized, unserviceable passenger-carrying vehicles may be exchanged as part payment for new passenger-carrying or freight-carrying vehicles, but unserviceable freight-carrying vehicles may be exchanged only for new freight-carrying vehicles.

*Abandonment of property.*—If property is so unserviceable that the expense of holding an auction sale of it is unwarranted, it may be abandoned after submitting an inspection report (Form 9-047) and obtaining the approval of the Director. (See p. 18 for instructions concerning abandonment of automobiles.)

*Lost or stolen property.*—If any Government property is lost or stolen, a report must be made promptly on Form 9-445-b and explained fully on Form 9-048; Form 9-061 should be used for livestock, and reasonable charges for recovering animals are allowed.

*Returned property.*—All property that is being returned to the division of field equipment must be reported in triplicate on Form 9-445-b; no property will be accepted or credited until this signed form has been received. This report should be sent along with the bill of lading to the branch chief clerk; it must not be inclosed in the boxes shipped.

## CAMP ADMINISTRATION

If camp outfits are used, their character should be determined by the size of the party, the means of transportation, and the nature of the work. The party chief should insist on punctuality, order, and neatness. Proper discipline is absolutely essential to efficiency.

A United States flag and a Geological Survey pennant must be displayed over each camp.

Camp sites should be carefully selected and the tents arranged in definite order and not at random. Wagons and other vehicles should be parked on one side. Harness, saddles, etc., should be kept off the ground and either hung on racks or placed in the wagons. Animals should be corralled at a sufficient distance from the tents to prevent them from interfering with comfort and sanitation. The camp



should be kept neat at all times; no loose articles, papers, or refuse should be allowed to litter the grounds.

Chiefs of parties should formulate sanitary regulations for camp administration adapted to the locality and should see that they are rigidly enforced. Promiscuous drinking from streams, failure to use boiled drinking water, carelessness in selecting camp sites, inadequate provision for the disposal of refuse, failure to observe sanitation in the arrangement of toilet facilities, insufficient screening from flies, and failure to use mosquito netting in malarial districts are responsible for most of the sickness in camp. (See "Typhoid-fever prevention," p. 12.)

*Subsistence.*—The Geological Survey allows a per diem in lieu of subsistence for camp parties. The following ration list is recommended as a general guide. Experience has shown it to be ample in amount for all essential articles.

*Ration list for topographic field parties<sup>1</sup>*

[100 rations]

Fresh meat, including fish and poultry	pounds	100
Cured meat, canned meat, or cheese	do	50
Lard	do	15
Flour, bread, or crackers	do	80
Cornmeal, cereals, macaroni, sago, or cornstarch	do	15
Baking powder or yeast cakes	do	5
Sugar	do	40
Molasses	gallon	1
Coffee	pounds	12
Tea, chocolate, or cocoa	do	2
Milk, condensed	cans	10
Butter	pounds	10
Dried fruit	do	20
Rice or beans	do	20
Potatoes or other fresh vegetables	do	100
Canned vegetables or fruit	cans	30
Spices	ounces	4
Flavoring extracts	do	4
Pepper or mustard	do	8
Pickles	quarts	3
Vinegar	quart	1
Salt	pounds	4
Miscellaneous items:		
Soap	bars	12
Sapolio	cans	4
Matches	boxes	24
Candles	dozen	4
Paper lunch bags		100
Kerosene	gallons	15

<sup>1</sup> The following substitutions may be made: 8 eggs for 1 pound of meat; 5 pounds of fresh meat for 2 pounds of cured meat; 5 quarts of fresh milk for 1 can of condensed milk; 5 pounds of fresh fruit for 1 pound of dried fruit; 3 pounds of fresh vegetables for 1 pound of dried vegetables.

*Rations for stock.*—For stock the following ration may be used as a basis for estimate:

*Daily ration, in pounds, for stock*

	Oats <sup>a</sup>	Corn <sup>a</sup>	Hay
Heavy horses.....	12	15	24
Mules.....	10	12	20

<sup>a</sup> The rations of oats and corn are substitutes for each other.

*Camp equipage.*—In order to facilitate field work in regions where camping is necessary or desirable, parties will be furnished with complete camp equipage, including tents, stoves, camp furniture, mess and cooking outfits, as well as means of transportation, such as wagons, automobiles, and other vehicles, harness, riding saddles, packsaddles, and necessary accessories.

*Camp beds.*—When necessary, a camp bed, consisting of one folding cot, two lamb's wool comforts, one woolen double blanket, one pillow, and one canvas bed cover, will be supplied for each permanent employee, on properly approved requisition through the Washington office. Temporary employees must furnish their own beds except on special field trips in which standardization of equipment is required.

*Care of camp property.*—As wear of camp property results mostly from carelessness in packing, loading, and transporting when camp is moved, party chiefs should take pains to instruct their assistants as to proper methods of handling it. Wagons should be painted and harness should be oiled as often as is necessary to keep in good condition. The teamster should be required to give proper attention to these details.

*Storing and pasturing.*—Storing should be done with order and system. The materials should be placed in boxes, the boxes numbered, and lists made of the articles in each box. The boxes should be securely packed and nailed, so that, if necessary, they may be safely shipped by rail. When wagon outfits are used the boxes may be left on the wagons ready to haul away. Precautions must be taken to protect property against dampness and rodents. Tents, harness, blankets, etc., must be thoroughly dried before packing; otherwise they will be ruined by mildew. Axles of vehicles must be cleaned with coal oil and well covered with axle grease. Cooking utensils and tableware must not be packed unwashed but must be thoroughly cleaned and dried. No food, matches, or grain should be stored.

Chiefs of parties must exercise great care in selecting proper localities and responsible caretakers for public animals to be placed in pasturage. Shelter, water, and character of forage, as well as the reliability of the caretaker, should govern selection. All shoes should



be removed, and an inventory and a complete description of all animals should be made before they are delivered to the caretaker. (See "Inventories," pp. 13-14; "Contracts for storage," pp. 12-13.)

*Entertaining persons in camp.*—Chiefs of parties and all other employees of the Survey are cautioned against entertaining in camp, when on field duty, any persons in a manner calculated to interfere with public business or to entail public expense.

*Personal baggage.*—Personal baggage should consist of essentials only and should be carried in canvas bags, suit cases, or locker trunks. Large trunks should not be taken to camp, except where they can be readily transported by wagon or rail.

## GENERAL INFORMATION

### AUTOMOBILES

*Purchase of automobiles.*—Automobiles must not be purchased without authority from the chief topographic engineer. A report on Form 9-057 of the engine and body numbers, make and type of car, Survey identification tag number, and date and place purchased must be made for new automobiles.

*Purchase of automobile tires and tubes.*—Chiefs of parties should anticipate their needs for tires and tubes for each quarter and be prepared to order them through the division engineer when a call for a definite quantity order is made. Vouchers in payment of emergency purchases in the field must be accompanied by a brief note addressed to the division engineer, explaining the emergency purchase and giving the reason why these supplies were not procured from the Washington office.

*Identification tags for Survey automobiles.*—When automobiles are purchased a set of tags bearing a Survey number are sent from the Washington office and should be attached to the machine. Paper Survey emblems, one to be attached on each side of the car, are also furnished. All Geological Survey automobiles must carry Survey emblems as well as tags, and request should be made for them if they are not already on the car. In placing emblems on the car a light coat of shellac or varnish for outside protection is desirable. Unnumbered tags to replace lost or defaced tags will be sent upon request, the same number to be painted on them.

*State licenses.*—The United States Government does not recognize the right of State officers to enforce State laws so as to require Federal employees (including temporary employees) to submit to an examination or to obtain State permits to perform their official duties. (See Supreme Court decision 289, October term, 1920.) This policy applies to drivers' licenses and State registration tags. Some States furnish without charge special Federal registration tags,

and tags so furnished should be carried on Survey cars, but one of the Survey identification tags should also be fastened inside the car. If a Survey employee is arrested for failure to have a State driver's license or a State registration tag, the fact should be reported to the nearest United States district attorney and to the chief topographic engineer. The Survey will not condone violations of traffic regulations and will take proper disciplinary measures if such violations are reported. Every driver of a Survey car is expected to be capable of handling it and to observe all local traffic regulations.

*Care of automobiles.*—Survey automobiles are intended for official use only. Repairs should be made promptly and with as little time lost to field work as practicable. All parts requiring oil or grease must be examined frequently, and all bolts and nuts must be kept tight. Radiators should be kept full of water, and attention must be given to storage batteries every 10 days.

*Maintenance-cost record for automobiles.*—A cost record is being kept on all cars purchased since January 1, 1926. Field engineers will keep a supply of automobile maintenance account blanks (Form 7876) and from them must compile a monthly automobile cost sheet in duplicate, one copy being forwarded to the Washington office and one copy being retained for future use. The cost sheet should show the total quantity and total cost of each item of expense. From these records the upkeep cost per mile will be computed in the Washington office. To obtain accurate mileage records it is necessary that speedometers on all cars purchased since January 1, 1926, be kept in good adjustment.

*Storage of automobiles.*—Automobiles should be stored in a fire-proof building. Air should be let out of tires, if necessary, and the cars jacked up. Storage batteries should be taken out and provision made for recharging them monthly. A single contract should be made for all Survey cars in the vicinity at a rate of so much per car per month, so that cars can be added or withdrawn without necessitating a change in contract. (See "Contracts for storage," pp. 12-13.)

*Abandonment of automobiles.*—If an automobile is so unserviceable that the expense of holding an auction sale of it is unwarranted, it may be abandoned after submitting an inspection report (Form 9-047) and obtaining the approval of the Director. Serviceable parts should be taken out for use on other machines. When engines are interchanged, a report must be made, giving correct numbers. All tags from automobiles that are sold, exchanged, or abandoned must be forwarded to the division of field equipment. (See p. 14 for instructions concerning transfer or sale of automobiles.)

*Automobile accidents.*—Drivers of Geological Survey cars must drive carefully. All accidents must be immediately reported to the chief topographic engineer. Should there be a possibility of arrest



or of a suit for damages, complete details should be wired to him, and he will request the Department of the Interior to ask the Department of Justice to assign the nearest United States district attorney to defend the case. Survey employees should not pay charges for damages unless the damages are due to their personal negligence. If the claim is considered just, a voucher should be submitted to the chief topographic engineer, supported by evidence to show the obligation of the United States, and he will submit it as a claim.

*Travel in privately owned automobiles.*—Prior authority must be obtained for travel in privately owned automobiles to and from field assignments. Requests for such authority should be made to the chief topographic engineer. A copy of this authorization or a reference to it must accompany voucher claims for reimbursement for expenses thus incurred.

#### OFFICE REPORTS

Every day's service of permanent employees, except administrative officers and clerks, must be reported on either an office or a field report blank. Each office report must show whether the service was performed in the District of Columbia or at a field office. Leave of absence preceded and followed by service in the District of Columbia should be so charged and entered on the Washington office report blank. Leave preceded by service in the District of Columbia and followed by service in the field or leave preceded by service in the field and followed by service in the District of Columbia should be counted as service in the District of Columbia if taken within the District of Columbia or as field service if taken outside. Office reports must not cover any service in the field or any travel to and from the field. Office reports are used both for work records and for pay-roll charges, and they must be so complete that there will be no uncertainty as to the amount of work done or the number of days spent on each particular job. Each day covered by the report should be accounted for, and, if practicable, Sundays, holidays, and leave of absence should be prorated against some particular job for which there is an allotment. However, periods of leave of one day or more should be indicated under "Remarks" for a check on office leave records.

#### REPORTS OF FIELD PARTIES

A monthly report is required from each chief of party on the topographic, transit-control, or level work done under his direction. Reports should be made out in triplicate unless otherwise instructed. One copy is sent directly to the chief topographic engineer, one copy to the division engineer, and one copy to the topographic engineer

in charge of the section. Reports should be complete in every detail and should include the names and work of all employees rendering technical service as well as the names and time of all temporary men employed during the month. Absence from duty through leave or other causes should be fully reported. Reports should be mailed not later than the first day of each month, as a summary must be submitted to the Director early in the month. At the conclusion of field work reports should be submitted promptly and should not be delayed by leave of absence or extended travel. The regular monthly form is to be used for topographic, triangulation, traverse, and level work, and a separate report must be made for each quadrangle and State. Diagrams should be carefully drawn, as they are used to keep the office progress maps up to date.

Expenditures for services in the District of Columbia are limited by statute, and it is necessary to keep a close check on such services. Therefore, reports of field parties must not include service in the Washington office or any field office. Travel to and from these offices and leave taken on the way should be included on the field report, and an office report should be submitted covering the time beginning with the day of arrival at the location of the office even though leave of absence may be taken at the location of the office before duty is begun.

Reports of "transfer of permanent and temporary employees" should be submitted to the chief topographic engineer when the transfers are made.

A report (Form 9-946) giving the names of the field assistants of grades 1 and 2 and the dates of their employment is required of all party chiefs. This report is to be made out at the end of each field season or on December 31 should field work be continuous. Recommendations concerning these temporary employees should be transmitted to the chief topographic engineer at the same time.

At the end of the field season a "certificate of users of Survey field property" (Form 9-036) should be filled out and transmitted to the branch chief clerk.

#### FIELD NOTEBOOKS AND RECORDS

Party chiefs will be held responsible for plane-table sheets, traverse sheets, field notebooks, and other valuable manuscript data until they are delivered to the agent of an express company or the registry clerk of a post office and a receipt is obtained. Field sheets should be protected from injury or loss and when completed should be sent to the proper office by registered mail or express. Should any maps or map material be carried to the Washington office in

personal baggage they must be delivered immediately on arrival to the section of inspection and editing for recording. Adjustments or corrections should not be allowed to accumulate but should be transferred promptly to the final field sheet. Information sheets, name sheets, road-classification sheets, and woodland sheets should be examined before leaving the field in order to insure complete data. Should maps and records be turned over to a successor in the field a receipt covering each item must be obtained. All party records and memoranda should be kept up to date and preferably in a separate file or book. Notebooks should usually be forwarded to the Washington office by registered mail, addressed to the chief topographic engineer. If duplicate data are entered in separate notebooks the books should be forwarded on different days, so that if either set is lost the other may be used. Every effort should be made to prevent the possibility of entire loss of results. Under no circumstance should valuable records be forwarded by ordinary mail.

#### CHANGES OF ADDRESS

All changes of address while in the field or on leave should be reported promptly to the chief topographic engineer, division engineers, and section chiefs. Arrangements should be made for the prompt delivery of mail, express, telegrams, and telephone messages. Addresses given on final party pay rolls and other vouchers should be correct, so that checks will be sent to the proper points. Individual addresses for members of the party should be given when necessary.

#### LEAVE OF ABSENCE

Permanent employees in the field desiring to take leave at the end of the field season should forward the request on Form 1-034 through their section chief long enough in advance to obtain approval of the request before the beginning of leave status. If the exact date is dependent upon the completion of the field work, and this date can not be determined in advance, the request should state the number of days desired, and when the exact date is known it should be communicated to the division engineer, who will insert proper dates on the leave request. Telegraphic requests for leave can not be charged to the Government.

#### UNPAID BILLS

Engineers should pay all outstanding bills before leaving the field and should make every effort to see that temporary assistants leave no unpaid bills.



## VOUCHERS

Engineers assigned to sections should submit all vouchers, reports, or other official papers to their section chief, who will forward them to the division engineer, unless specific instructions have been given to send the originals directly to the division engineer or to the Washington office, and copies of the reports and a summary of the vouchers to the section chief. Vouchers should be submitted promptly at the end of each month, and complete data as to appropriation, allotment, and cost should be entered on the memorandum copy. During the last quarter of the fiscal year the voucher should be submitted semimonthly. On June 1 an itemized estimate of expenditures for June should be submitted, and on June 16 a revised estimate for the last half of the month. All changes to be made on the Washington office pay roll should be reported by wire to the chief topographic engineer.

*Cost records.*—The entries at the top of a voucher under “Appropriation symbol” and “Allotment” are for the bookkeepers’ records and not for cost of work records. The field man should enter the appropriation and allotment in pencil on the memorandum copy of the voucher, and the section topographic engineer will verify these entries and stamp the correct entries on both original and memorandum copies. Cost records are kept by quadrangles or projects with the following entries: Field salaries, miscellaneous field expenses, office salaries, and miscellaneous office expenses. All salaries and miscellaneous expenditures should be classified as follows: Horizontal control, levels, aerial surveys, and sketching. The field engineers must enter this classification on memorandum copies of all vouchers, both Federal and State, and on memorandum copies of transportation requests and bills of lading. Under the heading “Salaries” will be entered all temporary salaries and full permanent salaries, including the retirement deduction. Under “Miscellaneous field expenses” will be entered all other field charges.

Cost records should therefore be entered on accounts by typewriter or in ink, in the following form:

Quadrangle	Field salaries	Miscellaneous field expenses	Horizontal control	Levels	Sketching	Total
Flint, Mich.....	\$200.00	\$50.00	\$50.00	\$75.00	\$125.00	\$250.00
Schoolcraft Mich.....	150.00	75.00	50.00	50.00	125.00	225.00
	350.00	125.00	100.00	125.00	250.00	475.00

If the voucher covers expenditures on only one quadrangle, omit the last line giving totals. If the voucher covers only one class of

work, such as sketching, omit the columns for other classes of work and the total column, and mark the sketching column "Total—sketching."

On Federal vouchers the cost entry will be made in the space for "Remarks," or in a party pay roll at the left of the title-page, the space marked "Classification summary" being left for a different classification which is to be reported to Congress. On State vouchers the classification will be made in the body of the voucher, below and to the left unless there is a suitable blank space elsewhere on the voucher. On memorandum copies of transportation requests and bills of lading the cost entry will be made directly below the statement of appropriation and allotment. (See fiscal regulations for specimen memorandum copies of vouchers.)

Expenditures for services in the District of Columbia are limited by statute, and every voucher, both Federal and State, covering payment for services in the District of Columbia, must carry on the memorandum copy the added entry "Service in D. C. ——— days, \$——." All other pay vouchers should carry the entry "No service in D. C." Leave of absence immediately preceded and followed by service in the District of Columbia will be counted as service in the District of Columbia. (See "Office reports" and "Reports of field parties," pp. 19–20.)

Supplemental instructions as to cost records and memoranda in regard to the submission of State and Federal vouchers will be given by the division engineer at the beginning of the field season and at such other times as may be necessary.

Memorandum copies of transportation requests and bills of lading must be transmitted through the division engineer to the chief topographic engineer immediately after the use of the original, and the cost of the service (estimated if necessary) should be indicated as well as the quadrangle or project charge. A record should be kept of transportation requests for use in preparation of travel-expense vouchers and of both transportation requests and bills of lading for use in preparation of monthly reports.

*Suggestions for rendition of vouchers.*—Most of the following suggestions are repetitions of the requirements of the Geological Survey's fiscal regulations, to which references by pages or paragraphs are made herein.

Follow specimen copies of vouchers given in fiscal regulations.

Items must be stated in chronologic order. (Par. 164 (c).)

The time of departure from and arrival at official headquarters must be stated. (Par. 164 (f) and par. (a) on p. 86.)

If meals are taken en route that should or might have been taken at official headquarters the necessity of so taking them must be explained.

Reference to the method of all travel must be made in the body of the voucher.

Transportation requests covering more than one person must plainly indicate the name of each person. This information must also be given in the voucher. An employee who renders a voucher involving transportation issued by another employee must mention that fact. (Par. 114 (b).)

Telegrams from Washington must be sent paid; telegrams to Washington must be sent collect and marked "Official business." Charges for telegrams between points in the field must be supported by copies of the telegrams, which must be receipted by the company's representative.

Each employee, either permanent or temporary, should submit his own travel-expense voucher, which must be certified to by the chief of party.

Form 1012 must be used as a voucher for per diem if travel is performed during the period it covers. Transportation requests or scrip must be mentioned in the body of the voucher (p. 94) and listed in the space provided for them.

The number of pieces of baggage transferred and the charges for the transfer must be stated. A charge for transfer of baggage in excess of 75 cents must be explained. (The notation "Usual charge" will suffice.) (Par. 126 and par. (c) on p. 86, as amended.)

A charge for excess baggage must contain, in addition to a statement of the points between which the baggage was shipped, the rate, the weight, and a statement that the excess consisted of Government property or of personal property carried for official use. (Par. 124 and par. (w) on p. 89.)

Charges for transportation (street car, bus, taxi, auto, etc.) between places of temporary residence and places of temporary employment are items of subsistence and are included in the maximum amount allowed by the travel order. (1 Comp. Gen. 403 and 773.) Charges for transportation between working points are items of travel. The charges of these two kinds should be clearly distinguished on the voucher.

A voucher covering a period in which leave is taken while the employee is in a "travel status" must state the hours at which official duty was stopped and resumed. (Pars. 150 and 154.) It must show plainly any detour made for personal convenience and must state the direct route of official travel. (Par. 122.) Meals taken just prior to or immediately after annual leave are usually not proper items for charges, and claims therefor must be explained.

If the account includes a period in which no expenses are charged, a reason for the break must be given. In other words, a voucher for



reimbursement of expenses for subsistence must show a complete history of the period it covers.

Charges for bus or taxi fares for personal transfer between station and hotel or hotel and station must state why street cars were not used. (Par. 126 and par. (o) on p. 88.)

The place where expenses were incurred must be indicated. This requirement includes expenses of all kinds—meals, lodging, or miscellaneous items. (Par. 164 (g).) For meals taken on train the phrase "en route" will suffice. The fiscal regulations do not permit a charge for cleaning clothes; they permit a charge for pressing only, and this charge is included in the allowance for subsistence or per diem. (Par. 137 as amended.)

The name of any person involved in an expenditure for which reimbursement is claimed must be stated. If charges are made for subsistence furnished for a driver or helper used in connection with the hire of an automobile, the name of the person from whom the car is hired must be given. (Par. 165 (j).)

A claim for reimbursement for a package shipped by parcel post must state the weight of the package and the points between which it was shipped. Government parcel-post packages may be insured the same as private shipments. (Par. 85 as amended.)

All vouchers for reimbursement of traveling expenses or subsistence other than those covering travel from and to headquarters should contain the statement "Continuing voucher; in field."

Every voucher and subvoucher must contain the name (not initials) and title of the person signing. (Par. 165 (m).) If any change is made in a subvoucher, it must be accompanied by the statement "Change made before signature by payee," and the statement must be initialed by the payee. (Par. 165 (g) and p. 89.)

Any unusual expenditure should be briefly explained.

All charges for automobile or livery hire, whether on direct vouchers or reimbursement vouchers, must contain the statement, if appropriate, "No other practicable means of transportation available." (Par. 125 (a) and par. (o) on p. 88.)

If an automobile or other conveyance, with a driver, is hired by oral agreement with the understanding that the Geological Survey is to pay for the subsistence of the driver, the items covering such subsistence must contain the driver's name and a reference to the person from whom the conveyance was hired, in order that the auditors can readily connect the two. (Par. (q) on p. 88.)

In submitting direct vouchers or reimbursement vouchers covering supplies, storage, etc., for a hired car, reference must be made to the person from whom the car was hired. (Par. 125 (e).) In order to prevent complications it is suggested that automobiles be hired with the understanding that the owner is to pay all charges

for repairs or replacements. If a rodman is hired with his car, the letter of employment should specify that the Geological Survey will pay for gasoline, oil, ferriage, tolls, and storage away from the owner's garage.

All charges for automobile supplies, hire, storage, etc., must contain one of the following notations: "Government-owned passenger car," "Government-owned truck," "Passenger car hired from ———," or "Truck hired from ———." (Par. 125 (e).) If a Government car, the number must be given.

Reimbursement from public funds for the hire of an automobile by one employee from another employee, or from any members of an employee's family, is not authorized. (See 4 Comp. Gen. 370.)

The dates of all expenditures must be shown. (Par. 65 (b).)

The unit price of articles must be given.

On principal vouchers the method of advertising or the absence of advertising must always be stated. If a purchase is made under the provision covering purchases amounting to not more than \$100 that fact must be indicated. The form of agreement must also be stated. (Pp. 39, 44.)

Certain States impose a consumer's tax on gasoline. This tax will not be paid by the Federal Government, and vouchers covering purchases of gasoline in these States must show whether or not they include the tax.

When a temporary employee is being returned to the initial point of employment or to his home, salary should also be paid for the period included in the travel, the only exception being that half-day salaries will not be paid and if the man reaches the point to which he is allowed traveling expenses before noon his salary will not be paid for that day. Transportation requests for such travel must be used whenever possible, and the trip for which salary and expenses are claimed must be one that is actually made. If a man elects to go to some other point than that to which he is entitled to travel, his account must state the travel that was actually made, and if the expense is greater than that authorized, the difference will be disallowed by the section of accounts.

#### FIGHTING FOREST FIRES

Chiefs of parties are directed to render such assistance as may be necessary for the suppression of fires in or threatening national forests and to respond promptly to emergency fire calls which the district forest officers may make. Fires discovered by members of Geological Survey parties which can not be put out should be reported to the nearest known forest officer immediately.

## PRIVATE INTEREST IN LANDS OR MINES

A provision of the organic law prohibits employees of the Geological Survey from having any personal or private interest in the land or mineral wealth of a region under survey and also prohibits them from making an examination or survey of property for private persons or for corporations.

## RELATIONS TO THE GOVERNMENT

Loyalty on the part of every member of the Geological Survey to the Survey as an organization and as a part of the Interior Department is essential to its continued efficiency and high standing.

The topographic branch cooperates with other branches of the Survey, and to render such cooperation effective the interests of the Survey as a whole must be kept in mind rather than the special interests of any particular branch or division.

Members of the topographic branch should keep themselves informed regarding Survey work in general and topographic work in particular. (See "Uses of topographic maps," pp. 28-29.)

The topographic branch is frequently called upon to cooperate with the General Land Office, the Bureau of Reclamation, the Forest Service, the Bureau of Soils, the Coast and Geodetic Survey, the Corps of Engineers, the Army Air Service, and other Government bureaus. Topographers assigned to such work should so far as practicable familiarize themselves with the regulations and methods of procedure of the cooperating bureau and should conform to them.

## RELATIONS TO STATE SURVEYS

It is essential to efficiency and economy that cordial relations exist between the United States Geological Survey and the State organizations with which it cooperates. When formal cooperation with a State is in force, engineers submitting expense vouchers should first familiarize themselves with the State methods of accounting so as to avoid confusion and delay in settlement of vouchers. State cooperating officials should be given every facility for examination of field sheets or control data whenever they desire to do so during the field season.

## RELATIONS TO THE PUBLIC

Courtesy to the public is enjoined on every member and employee of the topographic branch. Should persons make serious inquiry concerning work that the Survey is carrying on, time should be taken to give them the information, and when Federal and State



governments are cooperating Survey employees will be expected on all proper occasions to make known to citizens the relations of the State to the work which is being done.

Should chiefs of parties be requested to give out tracings of topographic field sheets, they should wire to the chief topographic engineer for instructions. Elevations of bench marks may be furnished to engineers or local officials, upon request, provided they are marked "Preliminary figures, subject to adjustment." Other incomplete data should not be furnished, but names and addresses of interested persons should be taken, so that the final results may be sent to them when available.

Objection is sometimes made to entry on private property by members of the Geological Survey engaged in official work, but it is believed that such objections may generally be overcome by an explanation of the public character of the work. Should the objections persist, the chief topographic engineer must be notified, and he will endeavor to obtain authority through the proper State officials. No forcible entry should be made. Laws enacted by certain State legislatures grant authority for entry on private property to officials of the United States Geological Survey.

#### INFORMATION TO THE PRESS

Employees in the field are permitted and even encouraged to make known the nature and character of their work and its relation to the other work of the Geological Survey and the Government. This may be done by carefully prepared statements to the press and by papers or talks before civic organizations.

However, no statements relative to the policy of the Geological Survey other than quotations from previously authorized statements may be given to the press without authorization from the Director. Whenever a member of the Survey is asked for a statement regarding official matters which involve Survey policies that have not been made public, he must, before giving it, obtain authorization from the Director. These restrictions apply to employees in the field as well as in Washington.

#### USES OF TOPOGRAPHIC MAPS

The need for topographic surveys may be measured in terms of the uses to which the resulting topographic maps are put. In general a topographic map is essential to any problem dealing with the use of the land. Specific examples of these uses are given below.

1. Natural-resources base map for Geologic Atlas of the United States; special geologic problems (economic, physiographic, etc.);

determination of the mineral and water resources; classification of the public lands; soil surveys; forest investigations.

2. Federal administration of national parks; national forests; national monuments; Indian, military, and game reservations; postal and rural delivery service; census service; transportation services; aerial navigation; education.

3. State administration by State engineers, State geologists, State foresters, State highway commissioners; in the location of State and county boundary lines; in the conservation of State resources; in legislation involving charters, rights, etc., of State agricultural colleges.

4. Military; as a base for military maps in the national defense; for maneuvers by the Army and National Guard; in the selection of routes of travel and transportation.

5. Engineering, in railroad and highway location; projects for power; irrigation, drainage, reservoir, and power sites and canal lines; affording bench marks and triangulation points for further large-scale surveys; river and harbor improvements.

6. Municipal administration of water supply; flood control; sewage disposal; establishment of local bench marks and triangulation; extension of city limits; changes in property lines; subdivision of land.

7. Aviation, in study of aerial routes, landing fields, etc.; data for preparation of special flight maps.

8. Educational, in teaching geography and physiography; as a base for miscellaneous educational studies.

9. Travel, as guide maps.

## COOPERATION IN TOPOGRAPHIC SURVEYS

### GENERAL CHARACTER

Cooperation in scientific work may consist in an exchange of information between two or more parties or in the expenditure by them of money for investigation or work in which they are mutually interested.

The United States Geological Survey has for many years cooperated with other bureaus of the Federal Government, particularly the Coast and Geodetic Survey, the Army Air Service, the General Land Office, the Bureau of Reclamation, the Corps of Engineers of the Army, the Bureau of Soils, the Forest Service, and the Weather Bureau, thus avoiding much expensive duplication of work. It has also received each year assistance in various forms from many individuals and corporations and has thus acquired much valuable information which otherwise could not have been

readily obtained. In return for this aid it has furnished maps and other publications to those assisting.

Cooperation to promote the common purpose of advancing knowledge and aiding development has existed between State organizations and the Federal Survey, and definite agreements were entered into early in the history of the Federal Survey. In the fiscal year 1885 it was agreed between the Director of the Survey and the Board of Commissioners of the State of Massachusetts that the topographic work in the State should be divided; that the State should pay one-half of the expense of field work and the Federal Survey one-half; and that the Survey should engrave the maps and give transfers from plates to the State commissioners.

Under terms varied to suit the conditions of each special case, agreements involving cooperation of some sort have been made between the Director of the United States Geological Survey and State officials of Alabama, Arizona, California, Colorado, Connecticut, Delaware, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, and Wisconsin.

The object of each State in these agreements was to direct and promote topographic mapping, to procure scientific information which it was not equipped to obtain, to insure completion of work at an earlier date than would be possible with the Federal or State appropriations alone, or to avail itself in some other way of the special facilities of the Federal Survey; the object of the Director was to expedite the work and carry it on with more detail in areas where the public interest was greatest, to encourage the development of scientific work of value to the people of the country, and to maintain cordial relations among organizations having an essentially common purpose.

On the completion of the field surveys by the Federal Survey, the resulting maps are published by the Government and thus become available to the State. If, for example, the cooperation covers even no more than the preparation of a topographic map, the State benefits by the fact that this will surely be followed more promptly than otherwise would be the case by geologic investigations and mapping, and by the study of mineral, water, and timber resources, for which the topographic maps are primarily prepared as bases.

The Federal Survey benefits by the extension of its legitimate operations made possible through cooperation with the States. The Survey is charged with the duty of making a topographic and geologic map of the entire area of the United States, as well as of studying its



water resources and reporting on its other economic products. The area that can be covered within a given time is increased by means of the greater funds available through cooperation, and the completion of the work is thereby hastened. This advantage is of especial importance in the work on the topographic maps, which form the bases for the studies of economic resources, geology, and hydrography and the classification of lands.

#### GENERAL POLICY IN COOPERATIVE WORK

From the experience gained, certain conditions essential to the success of cooperation have been established. All work which is in part paid for by the Federal Survey and whose results may be published by it or on its authority must be controlled by the Director. He selects assistants to perform such work or approves their selection. In its execution the work is subject to the supervision and approval of the appropriate chief of branch of the Federal Survey. Payments for continuous service on account of State cooperation can, under civil-service rules, be made to a State official only in case he also receives a Federal appointment. Each year plans and estimates for the season are mutually prepared, and a report of operations and results is submitted to the State officials as well as to the United States Geological Survey. All agreements for cooperation are drawn in such manner as not to conflict with the organic law of the Survey in regard to making or disposing of collections, furnishing information, or giving expert testimony.

One important point to be considered in all such work is that the general plans and methods of the Federal Survey can not be set aside on account of State cooperation. The only warrant for the Geological Survey to engage in cooperative mapping is to expedite the topographic mapping of the United States. In this work certain standards must be maintained, and the relative importance of different areas must be considered with relation to the general public benefit. Congress has recognized State cooperation but has so limited it as to require the States to bear all of the expense in excess of such an amount as is necessary for the Geological Survey to perform its share of standard topographic surveys, such share in no case to exceed 50 per cent.

The Federal allotments to meet State cooperation will bear their proportionate share of the expenses necessary in connection with the proper administration of the field and office work—namely, charges for internal administration of the topographic branch, for repair (but not for purchase) of instruments, for map editing, and for stationery, including field notebooks.

## METHODS OF COOPERATION

In the establishment and conduct of cooperative surveys certain methods which have been developed through an experience of over 40 years are followed.

The Director is requested by citizens of a State that may be interested in procuring topographic surveys to inform them as to his ability to accept such offers of cooperation as the State may be prepared to make, it being understood that efforts to secure cooperation must originate with the residents of the State. This Survey furnishes such information concerning the details of previous cooperative arrangements as may be sought. The object desired is usually attained by the introduction in the State legislature of a special bill or an item in the general appropriation bill providing for a cooperative survey to be conducted under the supervision of a State official or commission, who shall have control of the expenditure of the money appropriated, make agreements with the United States Geological Survey as to the methods of conducting the work, and recommend the order in which different portions of the State shall be surveyed. It is usually stipulated that the field operations shall be conducted under the supervision of the Director of the Geological Survey. This Survey furnishes expert assistants, who make the field surveys and office computations and draft the manuscript maps. The Federal Survey accepts the recommendations of the State officials for the employment of such temporary assistants as may prove qualified for the work, thus insuring the employment of residents of the State so far as practicable. The State law usually specifies that a sum equal to that appropriated by the State shall be expended in the same time by the United States Geological Survey.

The following sample act, passed by the Legislature of New Hampshire at its session of 1925, provides appropriations for the complete topographic map of a State:

To provide for the cooperation with the United States Geological Survey for the completion of the topographic mapping of the State of New Hampshire

*Resolved by the senate and house of representatives in general court convened:*

*Topographic maps.*—That in order to complete the topographic mapping of the State of New Hampshire and to revise existing United States geological maps of certain areas so that a complete and accurate map of the State of New Hampshire may be obtained to meet the urgent needs of the several State departments, the Federal Government, and all individuals who desire reliable information relative to the natural resources of the State, there is hereby appropriated the sum of \$25,000 annually for a period of five years for the cooperation with those branches of the United States Geological Survey engaged in such work, making a total of \$125,000 available, only on condition that the United States Government by its duly authorized agents apportion an equal amount to be expended for the same purpose within the State. That so much

of the annual appropriation as remains unexpended at the end of any fiscal year may be available for expenditure until the object of the survey is accomplished.

*Agreement for survey.*—That the governor and council are hereby authorized and directed to enter into such agreements with the Director of the United States Geological Survey as will assure that the surveys shall be carried out in the most economical manner and that the maps and data be made available for public use as early as practicable.

*Authority to cross land.*—That in order to carry out the purpose of this resolution all persons employed hereunder are authorized to enter and cross all lands within the State: *Provided*, That in so doing no damage shall be done to private property.

*Appropriation.*—That the sum of \$25,000 shall become immediately available upon the passage of this resolution and like sums for the fiscal years ending June 30, 1926, 1927, 1928, and 1929.

In some States an item in the general appropriation bill similar to the following was considered sufficient:

For cooperation with the United States Geological Survey in the preparation and completion of a contour topographic survey and map of this State, to be paid upon vouchers approved by the governor, the governor is hereby authorized to arrange with the Director or representative of the United States Geological Survey concerning this survey and map, its scale, method of execution, form, and all details of the work in behalf of this State, and may accept or reject the work executed by the United States Geological Survey, the sum of \$25,000.

It is hereby provided that said map shall accurately show the outlines of all townships, counties, and extensive wooded areas in this State as existing on the ground at the time of the execution of these surveys; the location of all roads, railroads, streams, canals, lakes, and rivers, and shall show by contour lines the elevation and depression of the surface of the country: *Provided further*, That the State shall pay not to exceed one-half of the cost of survey as completed.

In other States cooperation is arranged through some bureau having specific authority from the legislature, as shown in the Illinois law:

AN ACT To establish and create, at the University of Illinois, the bureau to be known as a State Geological Survey, defining its duties and providing for the preparation and publication of its reports and maps to illustrate the natural resources of the State, and making appropriation therefor.

SECTION 1. *Be it enacted by the people of the State of Illinois, represented in the general assembly*, That there be, and is hereby, created and established at the University of Illinois a bureau, to be known as a State Geological Survey, which shall be under the direction of a commission, to be known as a State Geological Commission, composed of the governor, who shall be ex officio chairman of said commission, the president of the University of Illinois, and one other competent person to be appointed by the governor, who shall hold office for the term of four years and until his successor is appointed and qualified.

\* \* \* \* \*

10. The said commissioners are hereby authorized to arrange with the Director or the representative of the United States Geological Survey in regard to cooperation between the said United States Geological Survey and the said Geological Commission in the preparation and completion of a contour topo-



graphic survey and map or maps of this State, and said commission may accept or reject the work of the United States Geological Survey.

\* \* \* \* \*

12. The commission may expend in the prosecution of such work a sum equal to that which shall be expended thereon by the United States Geological Survey, provided that not more than \$10,000 be expended in this work in any one year. [The appropriation for 1927 is \$50,000.]

In some States a department has funds appropriated for its general use which are available for miscellaneous work, and allotments from such funds are often made for cooperation with the Geological Survey without specific legislative authority.

#### BENEFITS OF COOPERATION

The appropriations made by the States for cooperative surveys are accepted chiefly for actual field work, in which are included the services of temporary employees, who are usually residents of the State, and for the living and traveling expenses of the field force. They may be used in paying office salaries only in so far as is necessary to equalize the expenses of both parties to the cooperation. Thus the larger part of the amount appropriated by the State is returned to its people. The appropriation of the Federal Government is devoted chiefly to paying the salaries of the permanent employees, a small portion of it being expended on general administration and a considerable portion on field and office work. The field work of the cooperative topographic surveys is invariably in charge of engineers of the Federal Survey, who are appointed under the rules of the United States Civil Service Commission by the Secretary of the Interior. Rodmen, recorders, chainmen, packers, teamsters, chauffeurs, cooks, laborers, and other minor assistants are employed in the locality in which the work is being done.

The topographic map is the base upon which the field investigations of geologists, hydrographers, and others are recorded and which makes possible a broader and more general study of the results of their work than is otherwise practicable. It was at once realized by State officials to whom such investigations had been assigned that an accurate and comprehensive performance of their duties was impossible without an adequate topographic base map. The expense of making such maps, however, was found to exceed in most localities the resources procurable through State aid, and the lack of the skilled men required in making such surveys was a barrier not easily surmounted. Competent topographic engineers are rare, and there is little inducement for young engineers of ability to make this their profession outside of the work of the Federal Government, as there is so little opportunity for steady employment in work of this kind elsewhere. It was apparent that in States availing themselves of the personnel and administrative knowledge of the Federal Survey the opportunities for systematic mapping would be greatly increased.

## STATUS OF COOPERATIVE WORK

State	Date of cooperation (fiscal years)	Cooperating agencies
Alabama.....	1900-1907, 1911-12, 1924-1927.....	State geologist.
Arizona.....	1919, 1920-21, 1926-27.....	State bureau of mines, governor through Bureau of Reclamation, State water commissioner.
California.....	1904-1927.....	State board of examiners, department of engineering, University of California, board of public service commissioners of the City of Los Angeles, Klamath-Shasta Valley irrigation district, East Bay municipal utility district, Los Angeles County surveyor, department of public works.
Colorado.....	1921, 1924-1927.....	State geologist, State engineer, State School of Mines.
Connecticut.....	1890-91, 1923-25.....	State board of commissioners, State highway commission. (State completely surveyed.)
Delaware.....	1926-27.....	State highway department.
Georgia.....	do.....	State geologist.
Hawaii.....	1910-1915, 1921-1927.....	Superintendent of public works, governor, commissioner of public lands.
Idaho.....	1913, 1920-1922, 1926.....	State engineer, State bureau of mines and geology.
Illinois.....	1906-1927.....	State geological survey commission, department of registration and education.
Indiana.....	1920.....	State geologist.
Iowa.....	1908-1917, 1919-1927.....	State geological survey.
Kentucky.....	1903-1917, 1919-1925, 1927.....	State commissioner of geology and forestry, State geological survey.
Louisiana.....	1903-04, 1907, 1910, 1923.....	Director of State experiment station, State geologist, board of commissioners, Fifth Louisiana levee district, department of conservation.
Maine.....	1900-1927.....	State survey commission, public utilities commission, State water-power commission.
Maryland.....	1897-1901, 1903-1912.....	State geologist. (State completely surveyed.)
Massachusetts.....	1885-1888.....	State topographic survey commissioners. (State completely surveyed.)
Michigan.....	1902, 1904-1921, 1926-27.....	State geologist.
Minnesota.....	1910-1917.....	State drainage commission.
Mississippi.....	1902-03, 1908-09, 1920-1923.....	Director of State experiment station, Tallahatchie drainage commission, State geological survey.
Missouri.....	1908-1916, 1920-1927.....	State bureau of geology and mines, State geologist.
Nebraska.....	1912, 1914, 1916.....	Board of regents of the University of Nebraska.
New Hampshire.....	1906, 1925-1927.....	Governor, State highway department.
New Jersey.....	1885-1887.....	State geologist. (State completely surveyed.)
New York.....	1893-1917, 1920-1927.....	State engineer and surveyor. (State completely surveyed; revision in progress.)
North Carolina.....	1897, 1902-03, 1906-07, 1909-10.....	Governor, State geologist, commissioner of the department of agriculture.
North Dakota.....	1920-21, 1923, 1926-27.....	State geological survey, State engineer
Ohio.....	1902-1916.....	Governor. (State completely surveyed.)
Oklahoma.....	1906-1908, 1912-1915.....	Territorial survey commission, State geological survey.
Oregon.....	1906-1917, 1922-1927.....	State bureau of mines and geology, State engineer.
Pennsylvania.....	1900-1915, 1919-1927.....	State department of forests and waters, State topographic and geological survey.
Rhode Island.....	1888-1889.....	Governor and three commissioners. (State completely surveyed.)
South Dakota.....	1922-23.....	State geologist.
Tennessee.....	1911, 1922-23, 1925-1927.....	State geologist, State department of highways and public works.
Texas.....	1902, 1905, 1910, 1915-16, 1920-1927.....	University of Texas mineral survey, State drainage and levee board, State bureau of economic geology and technology, State board of water engineers, State reclamation engineer, Harris and Orange Counties, Beaumont Chamber of Commerce.
Utah.....	1923-1927.....	Box Elder, Davis, Salt Lake, Toole, Utah, and Weber Counties.
Vermont.....	1914-1917, 1919-1927.....	Governor, State geologist.
Virginia.....	1909-1911, 1913-1927.....	State geologist.
Washington.....	1910-1925.....	State board of geological survey, State department of conservation and development.
West Virginia.....	1899, 1902-1916, 1919-1927.....	State geological survey, State geologist. (State completely surveyed; revision in progress.)
Wisconsin.....	1915, 1917, 1919-1927.....	State geologist.

## FUNDS EXPENDED FOR TOPOGRAPHIC MAPPING

*Funds allotted for topographic mapping, fiscal years 1880-1927*

Fiscal year	Federal funds				State funds	Total
	Scientific assistants	Topographic surveys	Surveying national forests	Military surveys and maps		
1880		<sup>a</sup> \$19,624.00				\$19,624.00
1881		<sup>a</sup> 44,541.00				44,541.00
1882		<sup>a</sup> 40,575.00				40,575.00
1883		<sup>a</sup> 70,700.00				70,700.00
1884	\$16,200	<sup>a</sup> 83,950.00				100,150.00
1885	16,200	<sup>a</sup> 144,665.00			<sup>b</sup> \$59,670.60	220,535.60
1886	16,200	<sup>a</sup> 168,310.00				184,510.00
1887	16,200	<sup>a</sup> 188,456.00				204,656.00
1888	16,200	<sup>a</sup> 186,111.00				202,311.00
1889	16,200	199,000.00			4,866.00	220,066.00
1890	16,200	200,000.00			<sup>c</sup> 24,599.21	240,799.21
1891	16,200	<sup>d</sup> 329,573.38				345,773.38
1892	16,200	250,000.00				266,200.00
1893	9,200	240,000.00			3,000.00	252,200.00
1894	9,200	200,000.00			24,000.00	233,200.00
1895	9,200	150,000.00			4,000.00	163,200.00
1896	9,200	150,000.00			5,000.00	164,200.00
1897	9,200	175,000.00			20,312.00	204,512.00
1898	9,200	175,000.00	\$150,000.00		16,000.00	350,200.00
1899	9,200	180,000.00	150,000.00		30,500.00	369,700.00
1900	9,200	240,000.00	130,000.00		45,000.00	424,200.00
1901	9,200	240,000.00	130,000.00		46,000.00	425,200.00
1902	9,200	250,000.00	130,000.00		96,500.00	485,700.00
1903	9,200	300,000.00	130,000.00		89,011.00	528,211.00
1904	9,200	300,000.00	130,000.00		105,750.00	544,950.00
1905	9,200	300,000.00	130,000.00		96,100.00	535,300.00
1906	9,200	350,000.00	130,000.00		103,300.00	592,500.00
1907	9,200	350,000.00	100,000.00		121,800.00	581,000.00
1908	9,200	300,000.00	100,000.00		103,850.00	513,050.00
1909	9,200	300,000.00	75,000.00		124,410.23	508,610.23
1910	9,200	350,000.00	75,000.00		180,689.36	614,889.36
1911	9,200	350,000.00	75,000.00		154,383.04	588,583.04
1912	9,200	350,000.00	75,000.00		177,353.00	612,053.00
1913	9,200	350,000.00	75,000.00		161,267.09	595,467.09
1914	9,200	350,000.00	75,000.00		179,047.96	613,247.96
1915	9,200	350,000.00	75,000.00		186,800.07	621,000.07
1916	9,200	350,000.00	75,000.00		166,789.39	600,989.39
1917	9,200	350,000.00	75,000.00	\$34,808.30	109,440.69	578,448.99
1918	9,200	350,000.00	75,000.00	553,328.49	56,000.00	1,043,528.49
1919	9,200	142,196.00	74,219.60	374,889.89	102,475.00	702,980.49
1920	9,200	325,000.00		259,040.13	190,904.46	784,144.59
1921	9,200	330,000.00		50,646.72	282,557.71	672,404.43
1922	9,200	330,000.00		14,321.72	230,848.81	584,370.53
1923	9,200	325,000.00		34,629.11	286,412.18	655,241.29
1924	9,200	500,000.00		36,048.41	353,198.22	898,446.63
1925	10,600	500,000.00		14,975.99	412,935.99	938,511.98
1926	11,000	<sup>e</sup> 558,300.00		11,227.96	344,950.14	925,478.10
1927		451,700.00		12,500.00	378,791.88	842,991.88
	461,800	12,737,701.38	2,234,219.60	1,396,416.72	5,079,014.03	21,909,151.73

<sup>a</sup> Allotted from general Survey appropriation.<sup>b</sup> Cooperative appropriation of \$40,000 in Massachusetts available for three fiscal years, 1885-87.<sup>c</sup> Continuous appropriation in Connecticut available for two fiscal years, 1890-91.<sup>d</sup> Includes deficiency appropriation of \$4,573.38.<sup>e</sup> Includes deficiency appropriation of \$73,300.

## REQUISITIONS

## STATIONERY

In ordering stationery it is advisable to request not more than three months' supply at one time. Requisitions should be made on Form 14618 or on a separate sheet of paper and should designate articles by numbers if any are known. Below are summarized the amount and kinds of stationery suitable for the field parties of



several classes. Schedules of general articles, any of which may be supplied to a party of any class, are given on page 42.

## TRIANGULATION PARTY

- 1 account book.
- 10 address, notifications of, 1-567.
- 2 automobile maintenance account books, 9-086.
- 12 automobile monthly cost sheets, 7876.
- 6 automobile, reports on condition of, 9-058.
- 6 automobile transfer records, 9-057.
- 6 bills of lading.
- 3 certificates of users of Survey field property, 9-036.
- 1 computation book, large, 9-889.
- 8 contracts, short form, 1-003 h.
- 4 employment, field, applications for, 9-067.
- 15 employment, letters of, 9-026.
- 2 employees, temporary, reports of, to Civil Service Commission, 9-946.
- 25 envelopes, standard letter size,  $3\frac{7}{8}$  by  $8\frac{7}{8}$  inches.
- 6 envelopes, white, extra letter size,  $4\frac{1}{2}$  by  $10\frac{3}{8}$  inches.
- 6 envelopes, manila, 5 by 10 inches.
- 6 envelopes, manila, 10 by 15 inches.
- 12 envelopes, addressed to topographic branch.
- 6 envelopes, return-penalty,  $3\frac{3}{8}$  by  $8\frac{3}{8}$  inches.
- 1 ephemeris of the sun and Polaris.
- 6 freight or express shipment, labels for, 9-050b.
- 2 geodetic coordinates, computations of, 9-902.
- 1 geodetic distances, computation of, 9-901.
- 4 injuries, forms for reporting.
- 1 ink, fountain-pen, wood case.
- 2 instruments returned to custodian, 9-445-b.
- 2 instruments, transfer of, 9-139.
- 2 leave of absence, applications for, 1-034.
- 1 logarithms, 7-place or 5-place.
- 10 mail forwarding cards, postmaster, 1-044.
- 10 mail, second class, labels for, 9-160.
- 1 natural sines and cosines.
- 1 paste, tube.
- 6 pencils, No. 4.
- 3 pencil tips, metal and rubber.
- 20 postal cards, plain, 9-482.
- 2 property, inventories of, 9-054.
- 6 receipts, proposal and acceptance, 9-007.
- 12 recommendations of temporary employees.
- 12 reports of field party, 9-908.
- 2 requisitions, instruments, 9-445-a.
- 1 rubber bands, box.
- 4 tags, instrument repair, 9-1021.
- 5 tags, linen, penalty or plain.
- 5 tags, linen, express shipment.
- 6 temporary receipts, freight and express, 9-994.
- 4 triangulation field notebooks, 9-912.
- 6 vouchers, pay, 9-013a.
- 6 vouchers, party pay and subsistence, 9-015.

- 15 vouchers, purchase, 9-012.
- 2 vouchers, subvoucher book, 9-017 (2 additional for camping party).
- 6 vouchers, traveling expense, with detached memorandum, 1012.

## PRIMARY-TRAVERSE PARTY

- 1 account book.
- 20 address, notifications of, 1-567.
- 2 automobile maintenance account books, 9-086.
- 12 automobile monthly cost sheets, 7876.
- 6 automobile, reports on condition of, 9-058.
- 6 automobile transfer records, 9-057.
- 12 bills of lading.
- 3 certificates of users of Survey field property, 9-036.
- 8 contracts, short form, 1-003 h.
- 8 employment, field, applications for, 9-067.
- 25 employment, letters of, 9-026.
- 2 employees, temporary, reports of, to Civil Service Commission, 9-946.
- 25 envelopes, standard letter size,  $3\frac{7}{8}$  by  $8\frac{7}{8}$  inches.
- 6 envelopes, white, extra letter size,  $4\frac{1}{2}$  by  $10\frac{3}{8}$  inches.
- 6 envelopes, manila, 5 by 10 inches.
- 6 envelopes, manila, 10 by 15 inches.
- 12 envelopes, addressed to topographic branch.
- 6 envelopes, return-penalty,  $3\frac{3}{8}$  by  $8\frac{3}{8}$  inches.
- 1 ephemeris of the sun and Polaris.
- 10 freight or express shipment, labels for, 9-050b.
- 4 injuries, forms for reporting.
- 1 ink, fountain pen, wood case.
- 2 instruments returned to custodian, 9-445-b.
- 2 instruments, transfer of, 9-139.
- 2 leave of absence, applications for, 1-034.
- 1 logarithms, 7-place or 5-place.
- 24 mail forwarding cards, postmaster, 1-044.
- 15 mail, second class, labels for, 9-160.
- 1,000 paper, manila, sheets 3 by 5 inches.
- 1 natural sines and cosines.
- 1 paste, tube.
- 10 pencils, No. 4.
- 4 pencil tips, metal and rubber.
- 20 postal cards, plain, 9-482.
- 1 primary-traverse computation notebook, 9-931.
- 10 primary-traverse distance record notebooks, 9-929.
- 12 primary-traverse field notebooks, 9-928.
- 2 property, inventories of, 9-054.
- 6 receipts, proposal and acceptance, 9-007.
- 12 recommendations of temporary employees.
- 12 reports of field party, 9-908.
- 2 requisitions, instruments, 9-445-a.
- 1 rubber bands, box, No. 32.
- 3 tags, instrument repair, 9-1021.
- 5 tags, linen, penalty or plain.
- 10 tags, linen, express shipment.
- 6 temporary receipts, freight and express, 9-994.
- 6 vouchers, pay, 9-013a.
- 6 vouchers, party pay and subsistence, 9-015.

- 15 vouchers, purchase, 9-012.
- 3 vouchers, subvoucher book, 9-017 (2 additional for camping party).
- 6 vouchers, traveling expense, with detached memorandum, 1012.

## PRISM-LEVEL PARTY

- 1 account book.
- 12 address, notifications of, 1-567.
- 2 automobile maintenance account books, 9-086.
- 12 automobile monthly cost sheets, 7876.
- 6 automobile, reports on condition of, 9-058.
- 6 automobile transfer records, 9-057.
- 6 bills of lading.
- 3 certificates of users of Survey field property, 9-036.
- 8 contracts, short form, 1-003 h.
- 6 employment, field, applications for, 9-067.
- 25 employment, letters of, 9-026.
- 2 employees, temporary, reports of, to Civil Service Commission, 9-946.
- 25 envelopes, standard letter size,  $3\frac{7}{8}$  by  $8\frac{7}{8}$  inches.
- 6 envelopes, white, extra letter size,  $4\frac{1}{2}$  by  $10\frac{7}{8}$  inches.
- 6 envelopes, manila, 5 by 10 inches.
- 6 envelopes, manila, 10 by 15 inches.
- 12 envelopes, addressed to topographic branch.
- 6 envelopes, return-penalty,  $3\frac{5}{8}$  by  $8\frac{3}{8}$  inches.
- 10 freight or express shipment, labels for, 9-050b.
- 4 injuries, forms for reporting.
- 2 ink, fountain pen, wood case.
- 2 instruments returned to custodian, 9-445-b.
- 2 instruments, transfer of, 9-139.
- 2 leave of absence, applications for, 1-034.
- 1 level book, bench-mark descriptions, 9-916.
- 4 level notebooks, yard rod, 9-940 and 9-940-a.
- 24 mail forwarding cards, postmaster, 1-044.
- 15 mail, second class, labels for, 9-160.
- 1 paste, tube.
- 6 pencils, No. 4.
- 20 postal cards, plain, 9-482.
- 20 precise levels, computation forms, 9-932a.
- 2 property, inventories of, 9-054.
- 6 receipts, proposal and acceptance, 9-007.
- 12 recommendations of temporary employees.
- 15 reports of field party, 9-908.
- 2 requisitions, instruments, 9-445-a.
- 1 rubber bands, box.
- 3 tags, instrument repair, 9-1021.
- 5 tags, linen, penalty or plain.
- 10 tags, linen, express shipment.
- 6 temporary receipts, freight and express, 9-994.
- 6 vouchers, pay, 9-013a.
- 6 vouchers, party pay and subsistence, 9-015.
- 15 vouchers, purchase, 9-012.
- 2 vouchers, subvoucher book, 9-017 (2 additional for camping party).
- 6 vouchers, traveling expense, with detached memorandum, 1012.



## WYE-LEVEL PARTY

- 1 account book.
- 12 address, notifications of, 1-567.
- 2 automobile maintenance account books, 9-086.
- 12 automobile monthly cost sheets, 7876.
- 6 automobile, reports on condition of, 9-058.
- 6 automobile transfer records, 9-057.
- 6 bills of lading.
- 3 certificates of users of Survey field property, 9-036.
- 8 contracts, short form, 1-003 h.
- 6 employment, field, applications for, 9-067.
- 15 employment, letters of, 9-026.
- 2 employees, temporary, reports of, to Civil Service Commission, 9-946.
- 25 envelopes, standard letter size,  $3\frac{3}{8}$  by  $8\frac{3}{8}$  inches.
- 6 envelopes, white, extra letter size,  $4\frac{1}{2}$  by  $10\frac{3}{4}$  inches.
- 6 envelopes, manila, 5 by 10 inches.
- 4 envelopes, manila, 10 by 15 inches.
- 12 envelopes, addressed to topographic branch.
- 6 envelopes, return-penalty,  $3\frac{3}{8}$  by  $8\frac{3}{8}$  inches.
- 10 freight or express shipment, labels for, 9-050b.
- 4 injuries, forms for reporting.
- 1 ink, fountain pen, wood case.
- 2 instruments returned to custodian, 9-445-b.
- 2 instruments, transfer of, 9-139.
- 2 leave of absence, applications for, 1-034.
- 1 level book, bench-mark description, 9-916.
- 3 level notebooks, primary, black cover, 9-903.
- 3 level notebooks, primary, yellow cover, 9-903.
- 24 mail forwarding cards, postmaster, 1-044.
- 15 mail, second class, labels for, 9-160.
- 1 paste, tube.
- 10 pencils, No. 4.
- 20 postal cards, plain, 9-482.
- 2 property, inventories of, 9-054.
- 6 receipts, proposal and acceptance, 9-007.
- 12 recommendations of temporary employees.
- 15 reports of field party, 9-908.
- 2 requisitions, instruments, 9-445-a.
- 1 rubber bands, box.
- 4 tags, instrument repair, 9-1021.
- 5 tags, linen, penalty or plain.
- 10 tags, linen, express shipment.
- 6 temporary receipts, freight and express, 9-994.
- 6 vouchers, pay, 9-013a.
- 6 vouchers, party pay and subsistence, 9-015.
- 15 vouchers, purchase, 9-012.
- 1 voucher, subvoucher book, 9-017 (2 additional for camping party).
- 6 vouchers, traveling expense, with detached memorandum, 1012.

## TOPOGRAPHIC PARTY (1 TOPOGRAPHER)

- 1 account book.
- 10 address, notifications of, 1-567.
- 2 automobile maintenance account books, 9-086.
- 12 automobile monthly cost sheets, 7876.

- 6 automobile, reports on condition of, 9-058.
- 6 automobile transfer records, 9-057.
- 2 Beaman alidade notebooks, 9-913a.
- 12 bills of lading.
- 3 certificates of users of Survey field property, 9-036.
- 8 contracts, short form, 1-003 h.
- 6 employment, field, applications for, 9-067.
- 15 employment, letters of, 9-026.
- 2 employees, temporary, reports of, to Civil Service Commission, 9-946.
- 25 envelopes, standard letter size,  $3\frac{7}{8}$  by  $8\frac{7}{8}$  inches.
- 6 envelopes, white, extra letter size,  $4\frac{1}{2}$  by  $10\frac{3}{8}$  inches.
- 6 envelopes, manila, 5 by 10 inches.
- 6 envelopes, manila, 10 by 15 inches.
- 25 envelopes, addressed to topographic branch.
- 6 envelopes, return-penalty,  $3\frac{7}{8}$  by  $8\frac{7}{8}$  inches.
- 10 freight or express shipment, labels for, 9-050b.
- 1 geographic tables and formulas, Bulletin 650.
- 4 injuries, forms for reporting.
- 1 ink, fountain pen, wood case.
- Ink, waterproof, black, red, green.
- 2 instruments returned to custodian, 9-445-b.
- 2 instruments, transfer of, 9-139.
- 2 leave of absence, applications for, 1-034.
- 10 mail forwarding cards, postmaster, 1-044.
- 10 mail, second class, labels for, 9-160.
- Paper, double mounted, 18 by 24 or 24 by 31 inches.
- Paper, manila, 3 by 5 inches.
- Paper, single mounted, 15 by 15 or 9 by 9 inches.
- 1 paste, tube.
- 3 pencil tips, metal and rubber.
- 10 pencils, No. 4.
- 2 penholders, drawing, writing.
- Pens, drawing, K. & E., Gillott's, 290, 291, 303.
- Pens, writing, stub, falcon, etc.
- 1 pins, pyramid.
- 10 postal cards, plain, 9-482.
- 4 property, inventories of, 9-054.
- 6 receipts, proposal and acceptance, 9-007.
- 12 recommendations of temporary employees.
- 12 reports of field party, 9-908.
- 2 requisitions, instruments, 9-445-a.
- 1 rubber bands, box No. 32.
- 2 Ruby erasers.
- 1 sandpaper pencil pointer.
- 1 stadia table, Johnson's.
- 1 stadia table, Anderson's.
- 12 tags, linen, express shipment.
- 6 tags, instrument repair, 9-1021.
- 6 temporary receipts, freight and express, 9-994.
- Tracing linen.
- Tracing paper, thin.
- Tracing vellum.
- 1 vertical-angle record, 9-914.
- 2 vertical-angle traverse records, 9-913.

- 1 vertical-angle tables, Davis's.
- 3 vouchers, pay, 9-013a.
- 3 vouchers, party pay and subsistence, 9-015.
- 12 vouchers, purchase, 9-012.
- 1 voucher, subvoucher book, 9-017 (2 additional for camping party).
- 4 vouchers, traveling expense, with detached memorandum, 1012.
- Water colors, saucers, and brushes.

The following articles are usually required in camping parties only:

- Auction sale, advertisement, 9-051.
- Auction sale, report of, 9-040.
- Flags.
- Livestock, description of, 9-061.
- Pasturage of public animals, proposal, acceptance, and receipt, 9-008.
- Property affidavit, 9-048.
- Property, inspection report of, 9-047.
- Storage of public property, proposal, acceptance, and receipt, 9-007.

The following articles may also be had upon request if not already supplied:

- Baldwin solar charts.
- Blotting paper, sheets.
- Canteens, 2-quart (on instrument requisition).
- Celluloid sheets, 18 by 24 inches, clear, frosted, or opaque.
- Clips, Gem, Mogul, etc.
- Fasteners, paper.
- Letter file, Favorite.
- Paper, carbon copy books, official.
- Paper, carbon sheets.
- Paper, manila covers, 18 by 24 or 15 by 15 inches.
- Paper, official letter.
- Paper, ruled, 8 by 10½ inches.
- Paper, scratch, note size.
- Pencils, Kohinor, 6-H, 7-H, 8-H, 9-H.
- Pencils, blue, green, red.
- Regulations of Geological Survey.
- Scales, plotting, flat boxwood, 1: 240,000, 1: 125,000, 1: 96,000, 1: 62,500, 1: 48,000, 1: 31,680, 1: 24,000, 1: 21,120, 1: 20,000, 1: 10,000; inches, tenths, and fiftieths; inches, tenths, and eightieths; also 1: 48,000 for chains. (Either of these may be made into Burkland sight alidades on request.)
- Sealing wax.
- Tacks, thumb.
- Telegram blanks, official.
- Topographic instructions.
- Water colors, burnt sienna, Prussian blue.

## INSTRUMENTS

Requisitions for instruments for individual field parties of the classes named below should be made on Form 9-445-a (white) and should be signed by or marked to be charged to the man who will be responsible for their use and custody:



## TRIANGULATION PARTY

- 1 aneroid.
- Bags, book, large or small.
- Batteries for flash lamps, round or flat.
- 2 compasses, prismatic.
- 2 glasses, field.
- 1 lamp, electric, hand.
- 1 plumb bob.
- 1 protractor, celluloid.
- 1 tape, steel, 6-foot.
- 1 tape, steel, 25-foot, meters on back.
- 1 theodolite.

## PRIMARY-TRAVERSE PARTY

- Bags, book, large or small.
- Batteries, flash lamp, large or small.
- 3 counters, hand.
- Dies, figures, 1 set.
- Dies, letters.
- 1 glass, field.
- 2 lamps, electric, hand.
- 11 pins, tally.
- 2 plumb bobs.
- 2 rods, range.
- 1 rod, stadia.
- 1 tape, 100-foot, steel.
- 2 tapes, 300-foot, steel.
- 1 tape-repair outfit.
- 1 transit, 30-second.

## PRISM-LEVEL PARTY (FIRST OR SECOND ORDER WORK)

- Bags, book, large or small.
- Bench marks, copper nails with washers.
- Bench-mark tablets (cooperative or standard).
- Cement, cans.
- Dies, figures, 1 set.
- Dies, letters.
- Drills, 1½-inch bit.
- Hammers.
- Hatchets.
- Keel, red or blue.
- 1 level, Locke.
- 1 level, prism.
- Paint, cans, with brushes.
- 2 pins, turning.
- 2 rods, yard.
- 1 tape, steel, 25-foot.
- 1 umbrella.

## WYE-LEVEL PARTY (SECOND OR THIRD ORDER WORK)

- Bags, book, large or small.
- Bench marks, copper nails with washers.
- Bench-mark tablets (cooperative or standard).

Cement, cans.  
 Dies, figures, 1 set.  
 Dies, letters.  
 Drills,  $1\frac{1}{8}$ -inch bit.  
 Hammers.  
 Hatchets.  
 Keel, red or blue.  
 1 level, plumbing.  
 1 level, wye, 18-inch.  
 Paint, cans, with brushes.  
 2 pins, turning.  
 1 rod, New York.  
 1 tape, 25-foot, steel.

## WYE-LEVEL PARTY (FOURTH ORDER WORK)

Bags, book, large or small.  
 1 glass, field.  
 1 level, 15-inch.  
 1 rod, Philadelphia.  
 1 tape, metallic, 50-foot.  
 6 keels, red or blue.

## PLANE-TABLE TRIANGULATION PARTY

1 alidade, 25-inch telescopic.  
 Bags, book, large or small.  
 1 compass, 4-inch.  
 1 glass, field.  
 Level bubbles (specify size wanted).  
 1 level, circular.  
 1 plane-table board, 24 by 31 inches.  
 Scales, plotting.  
 1 straightedge.  
 1 tape, metallic, 50-foot.  
 1 tripod, Johnson.

## TOPOGRAPHIC PARTY (1 TOPOGRAPHER)

1 alidade, 18-inch, telescopic.  
 1 alidade, sight, Burkland.  
 1 aneroid.  
 Bags, book, large or small.  
 1 compass, 4-inch.  
 1 counter, hand.  
 1 set dies, figures and letters VA.  
 1 glass, field.  
 Level bubbles (specify size wanted).  
 1 level, circular.  
 1 level, Locke.  
 1 plane-table board, 15 by 15 inches.  
 1 plane-table board, 18 by 24 inches.  
 1 protractor, celluloid.  
 1 rod, stadia.  
 2 rods, stadia, paper patterns.

- Scales, plotting.
- 1 straightedge.
- 1 tape, 50-foot, metallic.
- 1 tripod, Johnson.
- 1 tripod, Bumstead.

## STADIA-TRAVERSE PARTY

- 1 alidade, 18-inch, telescopic.
- 1 alidade, sight, Burkland.
- Bags, book, large or small.
- 1 compass, 4-inch.
- Level bubbles (specify size wanted).
- 1 level, circular.
- 1 plane-table board, 15 by 15 inches.
- 1 plane-table board, 18 by 24 inches.
- 1 rod, stadia.
- Scales, plotting.
- 1 tape, 50-foot, metallic.
- 1 tripod, Johnson.

## TAPE-TRAVERSE PARTY

- 1 alidade, sight, Burkland.
- 1 aneroid.
- Bags, book, large or small.
- 1 compass, 4-inch.
- 1 compass, pocket.
- 1 counter, hand.
- 1 level, circular.
- 1 level, Locke.
- 1 plane-table board, 9 by 9 inches, with compass.
- 1 plane-table board, 15 by 15 inches, with compass.
- Scales, plotting.
- 1 tripod, Bumstead.
- 2 tapes, rope.

## FOOT-TRAVERSE PARTY

- 1 alidade, sight, Burkland.
- 1 aneroid.
- Bags, book, large or small.
- 1 plane-table board, 9 by 9 or 15 by 15 inches, with compass.
- Scales, plotting.
- 1 tripod, Bumstead.





## B. TRIANGULATION

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Compiled by E. M. DOUGLAS

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### GENERAL CONDITIONS FOR MAP CONTROL

The boundary lines of all regular United States Geological Survey maps are parallels of latitude and meridians of longitude. In order that these shall be properly located and that intermediate points shall be placed in correct positions, some system of horizontal control is required. The method to be adopted for linear control should be fixed by the character of the country, one of the requirements being that all control work shall be so accurate that no errors will be apparent in maps several times as large in scale as those to be published. In mountainous regions or in hilly, partly timbered areas horizontal control is effected by a system of triangulation, the whole area being divided into triangles whose apexes are represented by stations established on prominent points several miles apart. The angles between each station and all others visible from it are carefully measured with a theodolite graduated to read angles by micrometer to two seconds of arc or by estimation to fifths of a second. One side of the triangles, called the base line, must be carefully measured with a steel tape, if its length has not been previously determined, account being taken of slope of the line, elevation above sea level, temperature of the tape, and other essential details; and for at least one station the exact latitude and longitude and also the azimuth of one of the lines leading from the station must be determined by astronomic observations or by a connection with stations previously located.

In heavily timbered areas, where it is difficult to see from any point more than a mile or two in any direction, horizontal control is best obtained from distances measured on the ground with a 300-foot steel tape, a record being made of angles measured with a transit at each bend in the line. Such control, called transit traverse, must begin and end at points whose positions have been previously determined, and regardless of the character of the country such control must be carried around the edge of each quadrangle and once across its center east and west.

Because of the great expense involved in base-line measurements and in the determination of positions from astronomic observations,

it is generally advisable to connect triangulation systems or traverse lines with positions previously determined, even though they may be a long distance away. There are now few localities in the United States that can not conveniently be connected with known positions, and therefore, before horizontal control work is begun, the records of the Coast and Geodetic Survey, the Lake Survey, the United States Army Engineers, and other Government organizations should be examined in order to ascertain what positions in or near the area to be surveyed have been determined and are available for use in the work in hand.

Wherever possible, geographic locations should be based on the North American datum (formerly known as the United States standard datum), for there is in many localities a considerable difference between the standard and astronomic data.

The results of triangulation or transit traverse by the Geological Survey can always be obtained by anyone having occasion to use them by applying to the Director, United States Geological Survey, Washington, D. C.

The United States Board of Surveys and Maps has fixed requirements for triangulation control, from which geographic positions are to be computed, as follows:

	First order	Second order	Third order
Average triangle closure.....seconds.....	1	3	5
Check on base.....	1:25,000	1:10,000	1:5,000

Triangulation by the Geological Survey as described on the following pages, which is intended for map control only, is classed by the Board of Surveys and Maps as of the "third order," consequently the triangles should close with an average error of not more than 5 seconds, and the check on the terminal line or base must not exceed 1 part in 5,000 of the length of the line. Triangulation of the two higher orders serves both for geodetic investigations and for map control. At present such work is carried on by the United States Coast and Geodetic Survey in accordance with special instructions prepared by that bureau.

## TRIANGULATION FIELD WORK

### GENERAL REQUIREMENTS

*Amount of control.*—At least three serviceable stations of the third or a higher order must be established for each quadrangle, regardless of the scale of the map, and as many more as may be necessary to afford adequate bases for plane-table control. In addition, a number of secondary points—such as church spires, windmills, water tanks,



trees, and in high mountain regions some of the more prominent summits—must be located by intersection and checked by angles from one or more stations or by the “three-point method,” which gives satisfactory results if a fourth point is sighted for a check. Where no such objects are available, at least two points should be flagged for intersection if practicable. These points are intended to afford supplemental control for the topographer and should be selected with special reference to their usefulness in that connection.

The triangulator is also expected to locate, when practicable, either by direct measurement from his stations or by the three-point method, conspicuous objects, marks on State and county boundary lines, and township and section corners. Especial attention should be given to township and section corners because of their recognized value in the control of the land-line net. The General Land Office will on request addressed to the Washington office detail a cadastral engineer to assist in finding and identifying corners of the public-land surveys.

*Selection of stations.*—Stations should be selected and signals built before any observing is done, and to this end the triangulator and his assistant should make a reconnaissance over the area to be controlled. This reconnaissance should be thorough enough to disclose every practical scheme of triangulation and the angles at each point should be measured with a prismatic compass and platted with the protractor so that the size and proportions of the figures may be ascertained. All preparatory work, such as setting tablets and posts, erecting signals and scaffolds, clearing lines of sight, and obtaining consent of the owner, if on private land, should be completed during this reconnaissance, so that the final observing may be performed with economy and dispatch. The reconnaissance affords the triangulator opportunity to acquaint himself with the shortest routes of travel, the best stopping places, the available camp sites, water holes, pastures, and trails, and the best routes for scaling each peak to be occupied; and it enables him to gain a familiarity with the special character of each station and its signal which will be invaluable to him in identifying the points when he sights them later on. Each station must be named, and as station names are to be published, efforts should be made to select those which have local significance. The name selected should be stamped into the metal station mark with steel dies.

*Figures.*—The most desirable groups of triangles consist of either quadrilaterals with both diagonals sighted or central-point figures with four to seven sides. The triangles composing these figures should be well proportioned, angles measuring not less than  $30^{\circ}$  nor more than  $120^{\circ}$  each. The scheme should not be allowed to dwindle down to single, unsupported triangles, and especial care should be taken to connect the work done with other work by means

of well-proportioned triangles. Overlapping figures or an excess of observed lines beyond those necessary to insure a double determination of each length are undesirable, although a diagonal through some figure may occasionally be valuable as a check. As a rule additional lines of this kind only complicate the main scheme without materially adding to its strength, and the numerous observations made for them are discarded by the computers as superfluous. Judgment is to be used in this matter, however, for in many regions the atmospheric conditions are exceedingly uncertain, and the observer can not always count on being able to see in both directions over every line that may be essential to the main scheme. In such regions it is well to err on the safe side and obtain too many data rather than too few.

Angles should be read to all prominent points outside of the area for use in future expansion, even though the points lack signals or are not sharply defined.

*Secondary points.*—In cutting in secondary points for topographic control it should be remembered that locations that depend on two sights only, even if the angles are of adequate size, are likely to be of doubtful value, because of the absence of any check on possible gross errors in observing or computing, or because of the possibility of mistakes in the identification of the points. An endeavor should therefore be made to obtain at least three sights to every secondary point, even if the triangles are not of the best shape. Observers are especially cautioned not to slight the location of secondary points merely because they happen to be of no importance in their scheme of figures. As the topographer may find it expedient to start his control from a secondary point, a blunder in the location of such a point may result in his starting with an erroneous base and having later to make corrections at a great cost.

*Consent of owner.*—Before a site for a station on private land is selected, the written consent of the owner should be obtained, if practicable, for establishing a permanent station mark and erecting the required signal. If a summit must be cleared of timber, or if lines of sight must be cut, the value of the timber to be cut should be definitely fixed and agreed upon with the owner before cutting is begun.

When it is necessary to clear away timber and the owner or agent for the ground can not be reached without great delay, three residents of the locality should be asked to appraise the value of the timber cut and to sign a written statement regarding it. This statement should be forwarded to the office of the Survey for consideration if a claim for damage is filed.

*Station marks.*—Triangulation stations must be permanently marked by standard bench-mark tablets, each tablet to be set in

rock in place or in the top of a concrete or stone pier. (See pl. 4 and also p. 120 of leveling instructions, for instructions in regard to setting tablets.) When practicable, bottles or other imperishable material should be left as subsurface marks.

Two or more permanent reference marks should be established about each station mark. These may consist of holes drilled in rock in place in which a metal reference mark tablet is to be fixed, with the arrow pointing toward the station; spikes in roots of trees; or large stones set solidly in the ground. The azimuth and the distance to each reference mark must be duly entered in the field record.

When old stations are revisited and any of the marks are found to be defective or to have been destroyed, new marks must be established in their places, and a report regarding them must be sent at once to the Washington office.

*Signals.*—Triangulation signals must be built with a view to their permanence as well as to their visibility. They may be of various forms, the form selected depending on the locality and the materials at hand. Thus, a signal on a bare mountain peak may be a rock cairn; one on a partly wooded summit may be a straight tree, the surrounding timber being cleared away; one on cleared land may be a tripod or quadripod. (See pl. 1.)

Rock cairns should be not less than 8 feet high and should be well put together, so that they will withstand strong winds and heavy snows. A pole or a small green tree placed in the top is of advantage in sighting.

Signal trees are most satisfactory if stripped of their branches, except a tuft at the top. They form the best of targets when sighted against the sky, but if they are to be sighted against a dark background, they should carry two triangular targets 3 to 6 feet on a side, placed at right angles to each other and covered with white cloth.

Tripods or quadripods should be built of sawed lumber if such material is available. For the legs and center pole 2 by 4 inch scantlings may be used; for the cross braces 1 by 6 inch boards. The base of the pyramid should be large enough to permit a theodolite to be set up under the center pole. In order to increase its visibility, boards may be nailed across the sides about a foot apart and covered with signal cloth, and cross targets may be attached to the center pole above the apex of the pyramid. The best colors for this cloth are white and black or white and red.

Most signals stand in exposed places and should be securely anchored to prevent their being blown over. The legs of tripods and quadripods should be placed in the ground at least 2 feet; each leg should be fastened to a "deadman" and the hole filled with thoroughly tamped earth or rocks, or else a stake 4 feet long should be driven into the ground at an angle with each leg and firmly spiked



to it. If the ground is too rocky to permit the digging of holes, a 4-foot crosspiece should be nailed to each leg at right angles flat on the ground and weighted down with rocks. Signals built on solid rock should be fastened to ring bolts leaded or wedged in holes drilled in the rock.

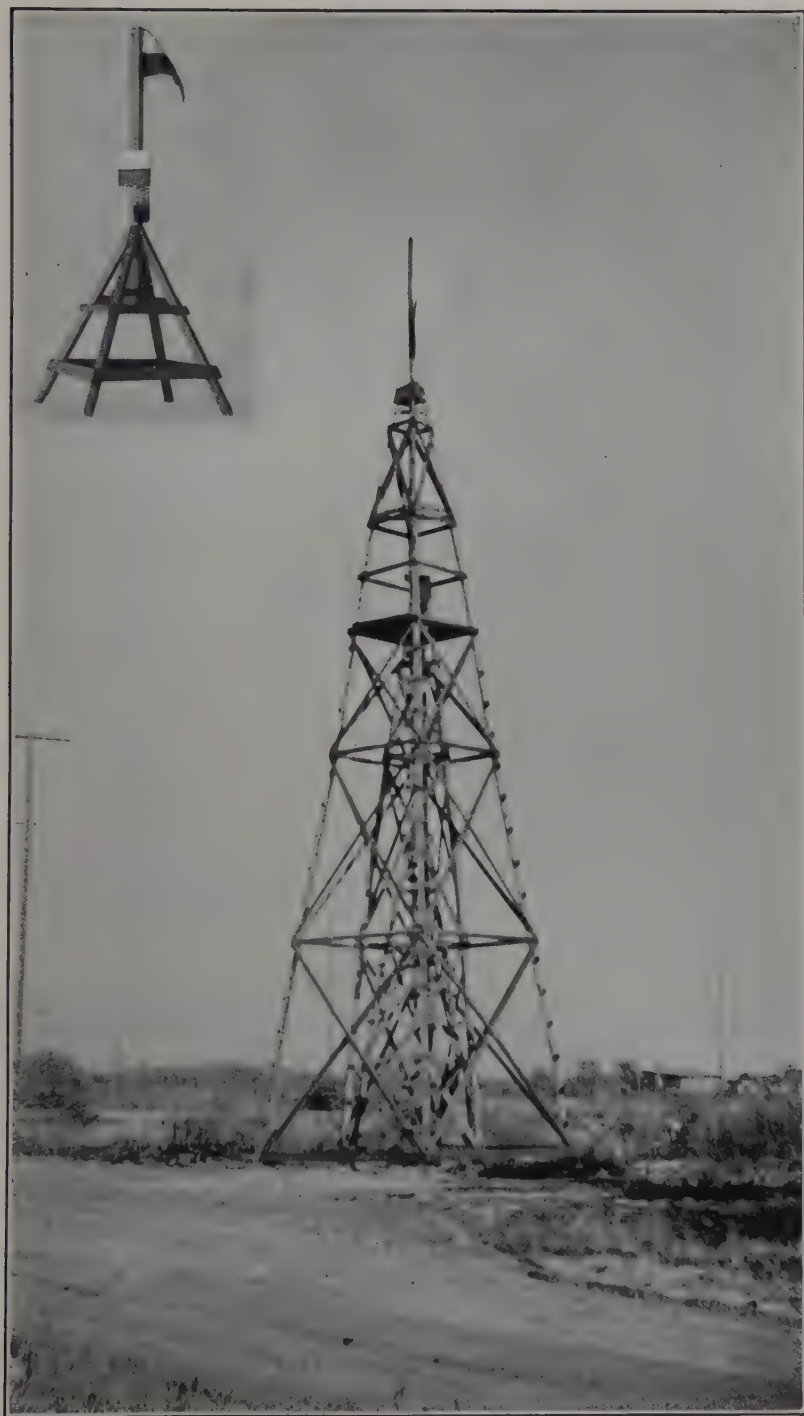
*Observing towers.*—High observing towers (pl. 1) should be avoided wherever possible, but where local conditions make them necessary provision should be made for determining the azimuth from the tower to some point visible from the ground. If no permanent object is visible, an azimuth mark should be set at least 500 feet distant and its direction determined, with at least one check observation. A description of the azimuth mark in sufficient detail to make its identification certain should be recorded. The distance to the mark from the station, either measured or estimated, should be stated. If it becomes necessary to elevate the instrument, a scaffold must be erected in the form of a tripod, capped with a thick board 12 inches square to support the instrument. Around this scaffold, but entirely independent of it, should be built another, in quadripod form supporting a platform on which the observer is to stand. If very high such a scaffold should be composed of successive bents, each 8 or 12 feet, with diagonal bracing. The outer scaffold is to serve also as a signal and for that purpose should extend at least 6 feet above the observing platform and be surmounted by a mast bearing cross targets. Before fixing signals in position the direction in which sights are to be taken should be carefully ascertained, so that no woodwork will interfere with the observations.

The size of the timbers to be used necessarily depends on the height of the structure. The amount of lumber required may be determined by means of a rough drawing of the structure to scale.

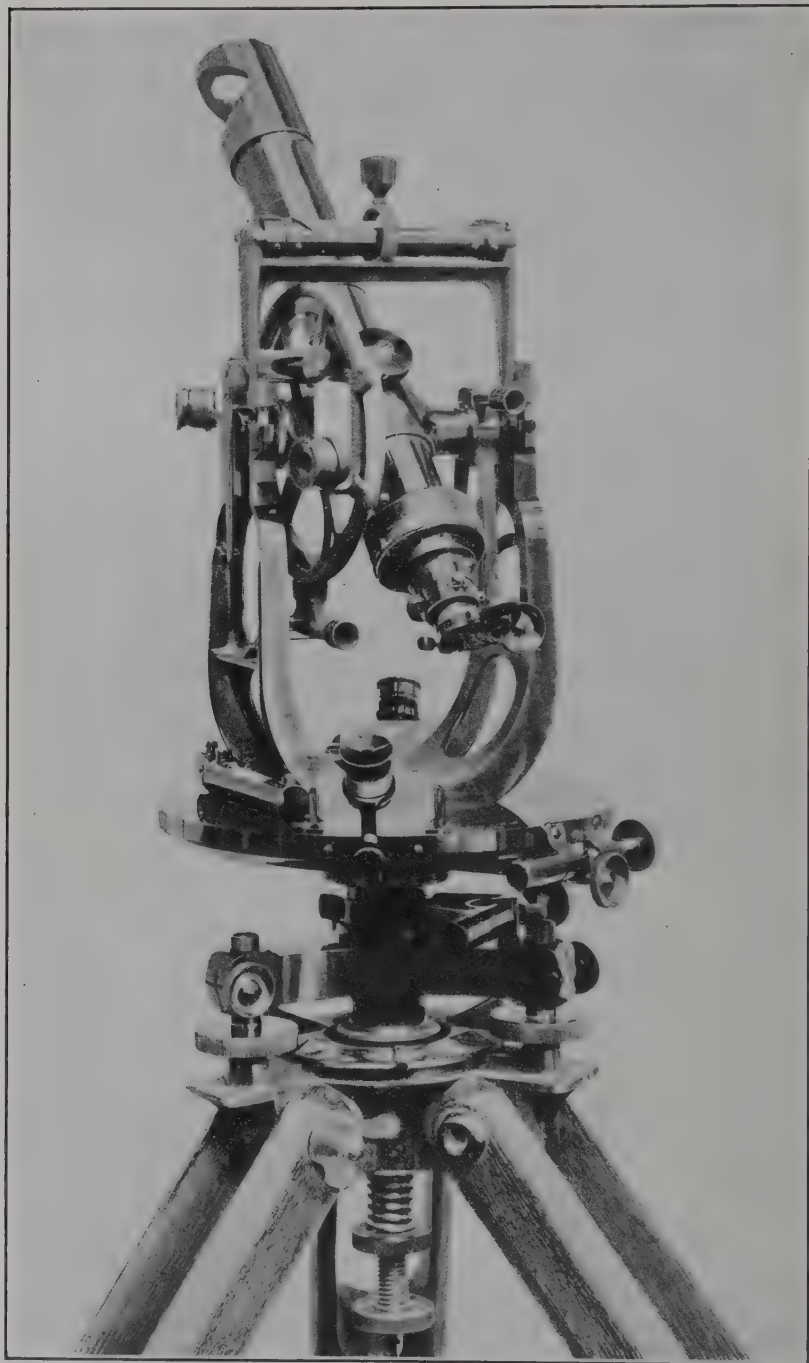
*Centering of signals.*—Signals should stand over station marks wherever possible, so as to avoid the necessity of computing swings for the angles. Great care must be taken to insure perfect centering of signal and scaffold over the station mark, a plumb bob being used for this purpose.

If centering the signal is impracticable, as it is with a tree signal, the distance and bearing of the signal to the station mark must be carefully measured and recorded.

The permanent mark, tablet, or concrete post must always be considered the station for which the geodetic position will later be computed, and when observations are made for angles the theodolite should be set up over its center if possible. If it is impracticable to center the instrument over the station mark, the distance between the point occupied and the station mark must be carefully measured and recorded. One or more sets of angles must also be read between the station mark and the other stations, in order of azimuth, preferably with the  $0^{\circ} 0' 00''$  for the pointing to the station mark.

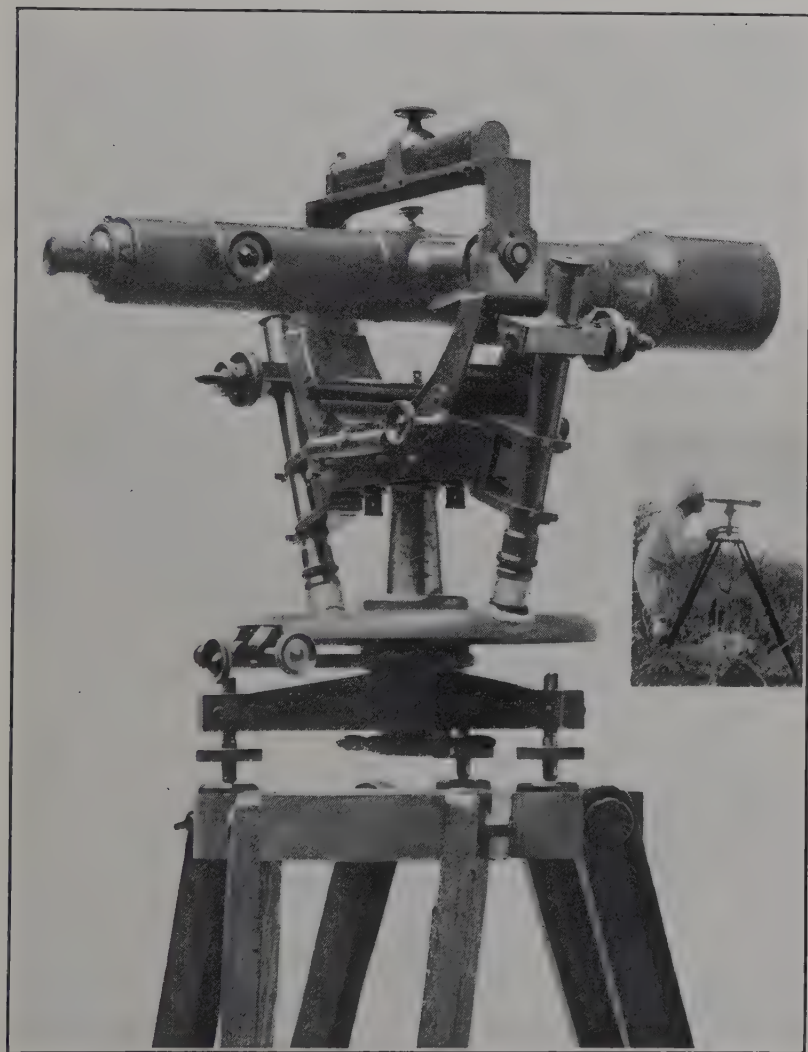


OBSERVING TOWER AND SIGNALS



VERNIER TRANSIT-THEODOLITE





MICROMETER THEODOLITE



GEOLOGICAL SURVEY MARKS FOR TRIANGULATION, TRANSIT TRAVERSE,  
AND LEVELING

*Heliotroping.*—The heliotrope outfit commonly used by the Survey is either the Steinheil or a plane mirror with a screw hinged to the back to give it universal motion and improvised diaphragms of tin or wood with round apertures. The plane mirror is generally preferred to a heliotrope of the more elaborate form.

A heliotrope is usually set up by mounting the mirror on a stake or board immediately over the center of the station and the diaphragm on another stake, 10 or 20 feet away, carefully aligned with the distant station. The operator must constantly watch the reflection from the mirror and keep it symmetrically over the aperture. If the sun is back of the observer a second mirror, a foot or two from the first, may be used to reflect the light into the first.

To the observer the flash should appear as a clearly defined point of light; if of appreciable size it will be necessary to bisect it, and an error is thus likely to be introduced. The apparent size of the flash depends more on the steadiness of the atmosphere than on the size of the aperture. An aperture greater than 1 inch will not be required in Geological Survey work.

#### PERSONNEL AND OUTFIT OF PARTY

In general each party consists of a chief of party, who acts as observer, and a recorder; also a cook and a teamster (or packer) when camping is necessary. Additional men are required for heliotroping, one for each heliotrope station, and local laborers may be employed to clear timbered summits or to erect large signals.

The following instruments and books are used in Geological Survey triangulation for map control:

- One 8-inch theodolite, with leather carrying case and shoulder straps, or a transit.
- Two pairs field glasses.
- One prismatic compass.
- One protractor (6-inch celluloid, full circle).
- One boxwood scale, graduated to inches and tenths.
- One 50-foot steel tape, meters on back.
- Two electric hand lamps.
- One 6-foot steel tape.
- Heliotropes.
- One plumb bob.
- Triangulation tablets.
- Cement, cans.
- Signal notices, printed on cloth.
- Climbing irons, for use in wooded regions.
- Sun umbrella } For use in regions where improvised sun and wind shelters
- Wind screen } can not readily be built.
- Triangulation field notes (9-912).
- Computation of geodetic distances (9-901).
- Computation of geodetic coordinates (9-902).
- Computation book, blank (9-889).
- Polaris positions for year.
- Geographic tables and formulas (Bulletin 650).
- Seven-place logarithmic tables.
- A good watch must be provided by the chief of party.



The following articles may be purchased in the field: Ax, hatchet, saw, nails, tacks, signal cloth, guy wire, stone drills (1½-inch bit), drill hammer, posthole digger, wire cutter, and brace and bits.

For the standard triangulation of the Geological Survey an 8-inch theodolite reading by micrometer to 2 seconds of arc or by estimation to one-fifth of a second is used.

For the horizontal control of small areas inside of large triangles or inclosed by belts of triangles, a vernier theodolite or transit may with the approval of the division chief be substituted for the more accurate micrometer theodolite.

### CARE OF INSTRUMENTS

Too much emphasis can not be laid upon the importance of care in the handling and transportation of instruments. Every employee intrusted with instruments in the field will be expected to keep them clean and in adjustment, to protect them from undue wear, and to return them to the custodian in fit order for use.

*Minor repairs.*—Each topographer should provide himself with a few simple tools and supplies, such as a small pair of pliers with side wire cutter, screw drivers of two sizes, small flat and round files, a spool of soft copper or brass wire, a few assorted brass nails and screws, a bottle of oil, a bottle of liquid shellac, spider web, and plaster of Paris, all of which may be used for minor repairs to instruments.

Field work should never be delayed by sending an instrument away for repair if the topographer can possibly repair it himself. Even crude repairs may often be made to serve until a new instrument can be procured.

*Setting of bubbles.*—For setting level bubbles a small supply of plaster of Paris should be kept on hand. For use the plaster should be mixed with water to the consistency of a thick paste. If plaster is lacking, strips of paper may be used, but these should never be jammed in very tight, as the pressure may distort the glass and thus vitiate the bubble reading by an appreciable amount. A reflecting surface of colored paper should be placed under the bubble in order to make the graduations more readable; a subdued green or blue tint is recommended.

*Mounting of cross wires.*—For mounting cross wires a small bottle containing shellac dissolved in alcohol, a pinch of beeswax, and a pair of dividers or a forked stick are needed. The best spider web is, of course, a freshly spun one from a small spider, for this will be both clean and elastic; but as spiders are not always available, it is well to keep on hand a spider cocoon. Such a cocoon will furnish webs enough to last for years, although with age the threads become stiff and brittle and therefore more liable to break from a jar to the

instrument. Most webs taken from grass or bushes are rough, coarse, and dirty.

To draw the reticule from the instrument, unscrew and remove the eyepiece slide; then take out two opposite capstan-headed screws and loosen the other two. Using the latter two as handles, revolve the cross-wire ring  $90^\circ$ , insert a pointed stick through the end of the telescope tube into a screw hole in the ring, and, using it as a handle, remove the other capstan screws and draw out the ring. To replace it in the telescope, reverse this procedure. When in place the cross wires should be on the side of the ring toward the eyepiece.

Having pressed a bit of beeswax to each prong of the dividers or forked stick, let a small web fall from the end of one of the prongs, or pick with it from a cocoon a single thread, pressing the thread into the beeswax, stretch the thread moderately, and attach to the wax on the other prong. If an old web is used, it should first be dampened by dipping in water for a few seconds. In place of the dividers or forked stick, small sticks or lumps of wax may be attached to the web about 2 inches apart. Place the web across the reticule, using a magnifier to insure its coinciding exactly with the marked lines. Put a small drop of shellac on each end and leave until dry.

*Cleaning instruments.*—Instruments having working parts exposed to air and dust require cleaning from time to time. Such exposed parts as the threads of tangent screws are particularly liable to collect dust and grit and should be wiped frequently with an oily rag, then rubbed dry. Only the best quality of clock or watch oil should be used for this purpose.

Steel tapes should be cleaned and oiled after use. All moisture or grit must be wiped from them each time they are reeled, or they will deteriorate rapidly.

Neither the object glass nor the eyepiece of a telescope should ever be rubbed with rough cloth or with the fingers, as the glass may thus be permanently scratched. The lenses should never be removed from the cell that holds them nor separated from one another.

*Packing and shipping.*—In shipping instruments by freight or express transit and theodolite boxes must be filled in with paper or cloth, so that if any part of the instrument should jar loose during the journey it may not roll around in the box and damage other parts. Heavy articles, such as compasses, aneroids, or other small instruments, should never be placed in the instrument box. The micrometers of theodolites should be wrapped tightly with cloth, as they are easily jarred loose. The same precautions should be taken when these instrument are to be transported by pack train.

On no account should any instrument be shipped by express or freight in its own case only. A wooden box, large enough to permit a

generous amount of excelsior, hay, or other padding around the instrument case, should be provided.

In mountains where pack trains are the sole means of conveyance the triangulator's outfit is most conveniently carried in a pair of canvas pack bags (alforjas), which must be properly balanced. The tripod, umbrella, and wind screens should be placed lengthwise on top, lashed to the saddle, and further balanced by properly disposing them on each side of the center. A canvas pack cover should be thrown over the whole and tucked in on all sides.

## ADJUSTMENT OF INSTRUMENTS

### PRECAUTIONS

The object glasses and eyepieces of all instruments must be properly focused. The cross wires projected against a distant object should appear immovable when the eye only is moved. Before the adjustments are commenced the instruments must be firmly set up and leveled. An instrument may appear to be out of adjustment simply because some part is loose. The object glass may be partly unscrewed or an adjusting screw may be only partly tightened; level bubbles or cross wires occasionally become loosened. Therefore, before commencing the adjustment of an instrument look out for such defects. When it is thought that an adjustment has been completed, always test it before using the instrument. All adjusting screws should be screwed tight enough to hold, yet not so tight as to injure the threads or put a severe strain on any other part. Especial care should be taken not to strain the cross-wire screws. Adjustments should be made in the order given under the following headings, for some adjustments depend on the accuracy of others previously made, and a change in any one may affect the others.

### MICROMETER THEODOLITE

*Striding level.*—Place the level (pl. 3) in the proper position on the telescope axis. Level carefully with the horizontal plates clamped, and rock the level slowly back and forth till the foot pieces strike. If the bubble leaves the center, bring it back by means of the side adjusting screws near one end of the tube.

Reverse the level and bring the bubble halfway back to the center by raising or lowering one end of the tube with the screw at that end and the other half with the leveling screws. Repeat these operations till the adjustment is perfect.

*Standards.*—After the striding level is in adjustment with the lower horizontal circle clamped, level the instrument in two positions at  $90^\circ$  from each other. Turn on the vertical axis  $180^\circ$  from one position; if the bubble runs away from the center, bring it halfway



back by loosening one of the large capstan-headed screws underneath the standards and tightening the other. Test the adjustment, and repeat it if necessary.

*Plate levels.*—Level instrument with the striding level only, then bring the bubbles of the plate levels to the center of their tubes by means of the end adjusting screws; or use the method described for adjusting the transit plate levels (p. 92).

*Micrometers.*—Each micrometer consists of three concentric tubes; the upper and lower ones slide in the central one. The lower tube, which holds the object lens when in proper position, is clamped to the middle one by means of the capstan-headed screw in the lower part of the **J**-shaped support. These two tubes may be moved together, or the lower one moved alone by loosening the proper screws. The upper tube contains the eyepiece lenses and is held in place by friction only.

Focus the eyepiece on the two parallel movable threads, and do not change it afterwards. With the eye in position for setting the micrometer, tighten one and loosen the other of the two screws that hold the **J**-shaped microscope support to the main frame of the theodolite until the figures and graduations on the plate appear to be in the center of the field.

Clamp the plate and by turning the micrometer screw set the two movable threads over a long graduation. Examine carefully to see whether they appear exactly parallel to it. If they are not parallel, loosen the two capstan-headed screws which clamp the micrometer tube, and twist the tube until the threads and mark appear parallel. Clamp the side screws lightly.

Set the movable cross wires on a division to the apparent left of the field of view as for a regular angle reading, read the micrometer head, and record the reading. Turn the graduated head about five turns, stopping when the threads are set on the next 10' division to the right; read and record. Repeat this operation several times. If the mean of the left-hand readings is the same as the mean of the right-hand readings, or within one division of it, the adjustment may be accepted as satisfactory. An actual count of full revolutions should be made at least once; otherwise the adjustment might wrongly be thought perfect for  $4\frac{1}{2}$  or  $5\frac{1}{2}$  revolutions.

When the space covered by the two parallel micrometer threads, moved by exactly five revolutions of the micrometer screw, appears to be longer than one 10' space on the graduated circle, to bring it into adjustment make the distance between the micrometer box and graduated plate longer by raising the middle part of the tube; but when the space is shorter than a 10' space make that distance shorter also—that is, consider as connected or dependent the length of the thread space covered by an even five revolutions of the micrometer

screw and the distance between the micrometer box and the graduated plate. When the former is longer than it should be, the latter should be made longer, if an adjustment is desired, and vice versa.

To make the adjustment, loosen the small capstan-headed screws which clamp the microscope tube; then, if the thread space is long, twist the middle part of the tube (including the micrometer box) back and forth and at the same time pull it upward, thus lengthening the distance to the graduated plate. When by estimation it has moved far enough, which can be roughly determined by the amount of blurring that results from the lower lens being thrown out of focus, clamp the upper capstan-headed screw. The lower part of the microscope tube holding the objective lens must now be twisted and gently pushed downward till the graduations again appear in focus. If the movable threads and graduations are not then parallel, the upper screw must be again loosened and the tube turned far enough to make them parallel, after which both screws must be tightened. Test the adjustment by again measuring a 10' space with the micrometer. If it is still out of adjustment, repeat these operations till it is satisfactory. When the adjustment has been completed a scratch may be made on the tube below each support and used as a guide in future adjustments.

The opposite micrometers may be placed  $180^\circ$  apart by setting one at a reading of  $0^\circ 0' 0''$ , with the comb scale exactly centered, and then centering the comb scale of the other micrometer over the  $180^\circ$  mark by means of the capstan-headed screw at the left-hand end of its box. Bring the micrometer threads over the  $180^\circ$  mark also; then, while holding the screw firmly in place, turn the graduated ring till it reads zero.

When setting the micrometer wires on a graduation, it is very important that they be moving toward the right when the turning of the screw is stopped. Should they be moved the least bit too far to the right, turn back not less than half a revolution of the screw and then bring them forward again. In general, when a setting is made by means of a screw working against a spring, the spring should always be undergoing compression when the motion stops.

*Cross wires.*—The vertical wire should be truly vertical; otherwise an exact adjustment of the cross wires is not essential.

After the striding level has been adjusted and the horizontal axis of the telescope carefully leveled, sight a distant point, raise and lower the telescope through an angle of  $5^\circ$  or  $10^\circ$ , and note whether the cross wires follow the point. If not, loosen the cross-wire ring and twist slightly; repeat the adjustment if necessary.

Hold the striding level on the telescope parallel to the optical axis and, with the bubble in the center of the tube, set the intersection of the cross wires on a distant point and clamp both plates; lift the

telescope out of its supports and turn  $180^\circ$  around its optical axis; set it again on the selected point. If the striding level when placed on top of the telescope is horizontal and the vertical wire still cuts the point, the adjustment is complete. If not, shift the cross wires in either direction by means of the capstan-headed screws for one-half the apparent error. Repeat the test till the error is nearly all eliminated. Finally readjust the vertical wire, if necessary; or both wires may be put in place by revolving them in temporary wooden Y supports.

#### TRANSIT THEODOLITE

The adjustments for striding level, standards, and plate level are the same for the transit theodolite (pl. 2) as for the micrometer theodolite.

*Collimation.*—Level carefully, sight on a point about 500 feet distant, raise or lower the telescope slightly, and note whether the vertical wire remains on the point; if not, loosen the capstan-headed screw and turn the cross-wire ring till the vertical wire will remain on the point when the telescope is raised or lowered. Clamp the instrument, set the vertical wire so that it cuts the point selected, transit the telescope by revolving it  $180^\circ$  on its horizontal axis, and select a second point 500 feet distant in the opposite direction from the first. Unclamp the upper plate, turn the transit  $180^\circ$  on the vertical axis, set it on the point first selected, and again clamp the plate. Transit the telescope, and if the vertical cross wire exactly bisects the second point its adjustment is perfect; if it does not, bring it one-quarter of the way back to the second point by turning the two capstan-headed screws on the sides of the telescope.

*Eyepiece tube.*—The eyepiece may be put into position over the cross wires by turning the screws that hold the eyepiece ring until the cross wires appear in the center of the field; an exact centering is not required.

*Telescope level.*—If there is a level attached to the telescope, it may be adjusted by the "peg method" after all the other adjustments are made, as follows. Level the transit and bring the bubble to the center of the tube under the telescope. Take a reading on a leveling rod or pole 300 or 400 feet distant, which is held on a stake set firmly in the ground. Revolve the transit  $180^\circ$  on the vertical axis and after again bringing the bubble to the center set a second stake at the same distance as the first and at such an elevation that the rod or pole reading is the same as on the first stake. The tops of the two stakes will then be at the same elevation. Move the transit 25 or 50 feet back of one stake and on a line with the other. Make the telescope as nearly horizontal as possible by means of the attached level, clamp it, and then take a reading on the rod held on the near stake and another reading on the distant stake. If the two readings agree,



the telescope is horizontal; if they do not agree, turn the tangent screw so as to bring the cross wire while set on the distant rod nearly to an agreement; repeat the operation until an agreement is reached. The telescope is then level, and the adjusting nuts at the end of the level tube should be turned until the bubble is brought to the center.

*Vertical circle or arc.*—The screws holding the vernier for the vertical arc should now be loosened and the vernier moved until the reading is  $0^{\circ}$  while the telescope is still level. If there is no level under the telescope, the level attached to the vertical-circle vernier arm may be adjusted after the striding level and standard are adjusted, by revolving the instrument on its vertical axis and turning the slow-motion tangent screw (attached to the vernier arm) until the bubble remains in the center during an entire revolution. The index error of the vertical circle may then be found, and the vernier moved till the reading is  $0^{\circ}$ .

### OBSERVING AND RECORDING

*Time of observing.*—As a rule, the best time for observing is during the three hours before sunset; the atmosphere is then steadiest and shows no "boiling." The early morning hours are occasionally good but are likely to be less satisfactory. Cloudy or overcast days may be favorable. As a last resort, observations at night may sometimes be necessary, but these require special night signals and assistants to operate them and because of the additional cost involved are seldom warranted.

*Preparation for observing.*—Wherever practicable the theodolite must be set over the station mark for reading angles, to obviate reduction to center. In setting up the tripod the head-bolt thumb-screws must be left loose until the legs are firmly placed and then tightened.

The instrument must be sheltered from both wind and sun. If the region affords no material readily available for constructing wind screens and sun shelters, a folding wind screen and a sun umbrella must be carried as a part of the regular outfit.

Before observations are begun at a station all adjustments of the theodolite must be tested and such as are found in error must be corrected, special attention being paid to the micrometers to eliminate errors of run. The stations to be sighted must next be carefully identified by means of the directions shown on the plat or by means of angles previously taken with a prismatic compass. If any of the distant stations can not be seen with the unaided eye, some object in line with each which can be found quickly must be selected, or, if necessary, the direction to each may be marked by some object near by, so that no time need be lost in making the pointings when the angles are being read.

*Method of observing.*—With micrometer theodolites either single angles may be measured or circle readings (directions) may be made. In using the latter method select for the initial point some station

that is especially distinct and easily sighted and use it as the initial point for all sets of readings. The telescope being set on the initial point, read both micrometers, then sight the other stations in succession in the order of their azimuths (clockwise rotations), closing on the initial point. Then reverse telescope, set on initial point, and sight the stations in reverse order. This completes one set of readings with telescope direct and reverse. Now shift the circle about  $45^\circ$  (examine the plate bubbles after this shift and releve if necessary) and begin another set. When pressed for time, shift the circle when telescope is reversed. No angle should be considered well determined that has not been measured on at least four different parts of the circle or eight times in all, four with telescope direct and four with telescope reversed. When the telescope is reversed, each end of its axis will rest in the same Y as before. Reversals and releveing are of especial importance where there is an appreciable difference in the elevations of the points sighted.

If the observations are made in the afternoon, take all secondary pointings before commencing the observations to stations, and make at least two sets of such pointings; the remaining time for observing can then be devoted to the accurate measurement of the important angles while conditions are the most favorable.

The graduated circle should never be placed so that when pointing at any particular station the micrometers will be set to even degrees, except, as before noted, while data are being obtained for "reduction to center."

*Field record.*—The field record is to be kept in book 9-912. It must be written in a plain neat hand with a No. 4 pencil or in ink, and no part of it must on any account ever be erased. A single line should be drawn through erroneous records, the corrected figures being written above. If deemed necessary, an explanation should be written in the column for remarks. The memory should not be trusted for data of any kind; the record must be faithfully kept in all particulars and must be made so complete that it can be understood by another person at any time.

On the flyleaf of each field notebook is a blank in which all information necessary to identify the book may be recorded. This blank should be filled so far as practicable on or before the first date of entry of field notes, and it must be completely filled before the book is forwarded to the Washington office. Any failure to fill in completely the blank on the flyleaf of a field notebook should be reported by the computer to the division engineer. One of the blank flyleaves must contain an index of the contents. The date, name of station, time of observing, and names of observer and recorder should be systematically entered at the head of each page.

The position of the instrument with respect to the center of the station must be clearly defined, and if it is set up off the center a full statement must be given of the distance and the angles measured.

On the page immediately preceding the record of angles should be written a minute and complete description of the station occupied, the station's marks, character of signal, nearest camping or other stopping places, roads, and trails, also a statement regarding the ownership of the land and such other information as will be helpful to the topographer. The description must be written before the recorder leaves the station and should be accompanied by a rough diagram showing directions to other stations and plan indicating location of instrument or signal if it was not centered on the station.

The following is a suitable station description:

ELK, LEWIS COUNTY, KY.

About 4 miles north of Petersville and 2 miles south of Glen Springs, on a cleared round knob at the head of Elk Lick and Black Lick, branches of Kinniconick Creek. George Washburn lives at base of hill on north side, and his place can be reached by road up Elk Lick. An excellent view in every direction.

Signal: Chestnut oak about 14 inches in diameter; distance 8.3 feet, true azimuth from station mark,  $58^{\circ} 11'$ .

Station mark: Stone post with tablet in top, set 30 inches in ground and resting on bedrock.

Underground mark: A + cut in rock.

A plat, drawn to scale, should always be prepared and forwarded to the office with the field notes.

*Reading and recording of angles.*—When the micrometer wires are set for a reading with the Geological Survey theodolites it is very important that the last movement of the wires be toward the right. The readings on the graduated head are then decreasing, and the spring attached to the slide that holds the wires is being compressed. If the cross wires are moved the least bit too far to the right they must not be turned backward merely to the setting but must be turned backward at least a half turn of the screw and then brought forward slowly to correct setting. When the setting is properly made a division on the graduated plate will appear exactly midway between the two movable cross wires, and an equal amount of white space will show on each side of it. A part at least of the micrometer adjustment in errors can be eliminated by making the settings with less than five turns of the screw; this can always be done if the right-hand part of the comb scale is sometimes used for comb-scale and micrometer-head readings, the 10-minute space being taken from the left.

For all precision instruments in which a tangent screw and spring are used together, the setting should be made while the spring is being compressed; otherwise the "slack" of the screw may cause an error.

The recorder should not only take down the readings called off by the observer but should without delay compute the angles between successive stations and also the mean readings. The following form is to be used for recording angles by the method of directions:



Station occupied, Elk. Date, January 6, 1925.		[Left-hand page.]				[Right-hand page.]				Observer, E. L. M. Recorder, R. C. S.	
Stations sighted		Microm. A		Microm. B		Mean		Angle		Remarks	
		° ' div.		° ' div.		° ' "		° ' "			
<i>Telescope direct</i>											
Dick	-----	303	53 06	123	53 04	123	53 10			Time 4 p. m. All signals distinct.  Eccentric point occupied, distant from station mark 1.43 meters (4.7 feet).	
Taylor	-----	349	29 21	169	29 23	169	29 44				
Browning	-----	30	03 03	210	03 04	210	03 07	45	36 34		
Tweedy	-----	127	13 13	307	13 10	307	13 23	40	33 23		
(Station mark)	-----	280	46 00	100	46 00	100	46 00	97	10 16		
Dick	-----	303	53 07	123	53 04	123	53 11	153	33 38		
<i>Telescope reversed</i>											
Dick	-----	123	53 01	303	53 02	123	53 03			Time 4 p. m. All signals distinct.  Eccentric point occupied, distant from station mark 1.43 meters (4.7 feet).	
(Station mark)	-----	100	45 27	280	45 26	100	45 53				
Tweedy	-----	307	13 08	127	13 08	307	13 16	38	36		
Browning	-----	210	03 02	30	02 29	30	03 01	153	32 39		
Taylor	-----	169	29 23	349	29 22	349	29 45	29	29		
Dick	-----	123	53 03	303	53 05	123	53 08	37	36		
(Station mark to left of Dick, 23° 07' 10'.)										40	33 19.20

In this example five sets of circle readings direct and five reversed were taken. The angles between stations were found by subtracting the mean reading at one station from that for the next following. They are grouped in these columns merely for convenience; they may fill several pages. The next group on this or a following page would represent the angle Browning to Tweedy, and so on.

Only two readings on the station mark need be taken for reduction to center.

Opposite each angle record any necessary information as to visibility of signals or atmospheric conditions.

*Field computations.*—Angles at each station should be reduced to center in the field in order to test the triangle closures, which for Geological Survey work should seldom exceed 10 seconds or average more than 5 seconds.

Arbitrary adjustments and preliminary computations of positions should also be made in the field. Book 9-889 should be used for summary of angles and for miscellaneous computations. Computations for distances should be entered in book 9-901 and for coordinates in book 9-902. For field computations of coordinates where the lines are short, five or six place logarithms will give sufficient accuracy, and the computations may be shortened by omitting some of the minor corrections, carrying results to tenths of seconds of latitude and longitude only.

As soon as the preliminary computations are made the record books should be sent to the Survey office by registered mail. The computation books should also be sent by registered mail but on another day.

*Triangulation plot.*—A careful plot of the work should be kept on the scale of 8 miles to an inch, and each month a reduced copy, on which angles measured are indicated by the usual sign, should be sent in on the monthly report blank. If this plot is carefully made it can be transferred directly to the office State progress map.

In order to use the plot for finding the direction to distant stations place the protractor on it with  $0^\circ$  in line with a station that can be seen clearly; then read in turn the angle to each other station, thus obtaining an observing list.

*Azimuths.*—Two true azimuths should generally be available for each square degree covered by the triangulation. These may be previously computed azimuths from independent sources or may be obtained by direct observations on Polaris.

*Azimuth observations.*—An azimuth mark should be placed at least half a mile from the station. It should consist of a vertical slit one-fourth to one-half inch wide and 6 inches long, cut in a small box containing a candle or lantern. To illuminate the cross wires of the instrument and to read the angles, an electric hand lamp is to be preferred.

The observations should consist of not less than five direct and five reversed measurements between the star and mark. As the star is at a much higher angle of elevation than the mark, it is important that the horizontal axis of the theodolite be adjusted with care and leveled. The ends of the striding-level bubble must be read at each setting on the star and a level correction computed if there is an appreciable difference between them, as shown in the example below.

Observations on Polaris should be made immediately before and after elongation, as any error in the time of observation has then the least effect on the resulting azimuth. The time of setting the cross wires on the star must be recorded to the nearest second. The watch error must be known, and to this end the observer should compare his watch frequently with telegraphic time, which is sent over Western Union lines once a day, usually at noon, Washington standard time. The time meridian for which the watch is set must always be recorded; if "daylight saving" time is used, that fact must also be stated.

*Example of record of azimuth observations*

Station: Elk, Ky. 8-inch theodolite No. 434. One division of micrometer = 2". One division of level = 2" of arc. January 6, 1925. Watch 0<sup>m</sup> 23<sup>ss</sup> slow, 75th meridian standard time

**Telescope direct**

Object	Time a.m.	Level		Micrometer						Mean	Angle				
		West	East	A			B								
	<i>H. m. s.</i>	<i>Div.</i>	<i>Div.</i>	°	'	<i>div.</i>	°	'	<i>div.</i>	°	'	"	°	'	"
Mark (1)-----															
Polaris (2)-----	1 10 50	11.0	10.0	352	54	09	172	53	21	172	54	00			
		9.0	12.0	288	35	24	108	35	05	108	35	29			
		20.0	22.0												
			-2.0										64	18	31

**Telescope reversed**

Mark (4)				172	53	04	352	52	13	352 52 47
Polaris (3)	1 16 48	11.0	10.0	108	34	10	288	33	27	288 34 07
		9.0	12.0							
		20.0	22.0							64 18 40
		-2.0								
Mark (5)				202	41	13	22	40	22	22 41 05
Polaris (6)	1 20 26	10.0	11.0	138	22	24	318	22	06	318 22 30
		10.0	11.0							
		20.0	22.0							64 18 35
		-2.0								

**Telescope direct**

Mark				22	41	07	202	40	17	202 40 54
Polaris	1 26 52	10.0	11.0	318	22	20	138	22	13	138 22 33
		11.0	10.0							
		21.0	21.0							64 18 21
		0.0								

NOTE.—Four other sets should be taken.



## TRIANGULATION COMPUTATIONS

Preliminary computations of distances from unadjusted angles should be made in the field, as required by the rule on page 64.

The steps in the final adjustment and computation are set forth below.

Operations are completed in books 9-912, 9-889, 9-901, and 9-902. The results are tabulated on printed blanks 8 by 10½ inches in size, one blank for each station.

### CLOSING THE HORIZON

In careful work closing errors will always be small and may be distributed among the angles in proportion to their number. If any of the angles measured should equal the sums of smaller angles, proper adjustments must be made before the horizon is closed.

### TABULATION OF ANGLES

For convenience of reference a rough plot should be made for each station on part of a page in book 9-889, showing the relative size and position of the angles with names of stations sighted, and on the same or the following page should be given a summary of all the angles at the station, in order of azimuth, with the angles and distances to signals for eccentric stations.

### REDUCTION TO CENTER

For eccentric stations the data for reduction to center should be indicated on the plat, and figures should be given for them in the summary. An illustration of the method of producing these data is given below. (See also fig. 2, p. 78.) Two sets of angles were read at Elk station (where an eccentric point was occupied), with one of the micrometers set very nearly on 100° 45' when the telescope was pointing directly toward the center of the signal. The angle to each point in turn is given below. By measuring the angle with one micrometer reading 0° 00' the computer would have been saved considerable trouble and the possibility of error would have been lessened. The measured distance between the center of the instrument and the center of the station was 4.7 feet (1.43 meters).

The formula for computing the swing in seconds for any line is:

$$\frac{\text{Distance to signal}}{\text{Sine } 1''} \times \frac{\text{Sine of angle between signal and far station}}{\text{Distance to far station}}$$

The distance to signal will be a constant for each set up, hence its logarithm may be combined with the sine of 1'' and this constant used throughout the computation. The distances to the distant stations in logarithms of meters are derived from a preliminary computation.

Log 1.43	= 0. 15534
Log sin 1''	= 4. 68557
Log constant	= 5. 46977

## ELK STATION

Station.....	Dick	Taylor	Browning	Tweedy
Angle.....	23° 07' 10"	68° 43' 40"	109° 16' 54"	206° 27' 10"
Log constant.....	5.46977	5.46977	5.46977	5.46977
Log sine angle.....	9.59400	9.96935	9.97493	9.64881
A. C. log distance.....	5.70154	5.59196	5.74781	5.63275
Log correction.....	0.76531	1.03108	1.19251	0.75133
Correction in seconds.....	+5.83	+10.74	+15.58	-5.64

The sign for any correction is the same as that for the sine of the angle, therefore for an angle over  $180^\circ$  it will be negative.

The correction for any angle will be the difference between the corrections for the two lines bounding it, the lines always being taken in order of azimuth.

Thus, for Dick-Elk-Taylor it will be

$$\begin{array}{rcl}
 +10.74 & & \\
 -5.83 & \text{For Browning-Elk-Tweedy it will be} & -15.58 \\
 +4.91'' & & -21.22
 \end{array}$$

The general rule is, change the sign of first correction (in order of azimuth) and add algebraically to the second correction. The sum will be the correction to the angle. The angles listed on page 72 have all been corrected.

The foregoing formula may be used also when it is desired to compute the swing for a line, which is to be applied at a distant station to change the pointing to the marked point—that is, the station center—from that taken to the signal. Whether the computed swing is to be added to or subtracted from a given angle may easily be found by an inspection of the diagram.

## COMPUTATION OF AZIMUTH OBSERVATIONS

The daily change in Polaris is so slight that for the following computation no account need be taken of a fraction of a day in computing its position:

Elk sta., Ky. Lat.  $37^\circ 28' 47''$ , long.  $82^\circ 00' 16''$ .

January 6, 1925, at  $1^h 10^m 50^s$  a. m. watch time.<sup>1</sup>

Watch 23 seconds slow, 75th meridian (standard) time.

Long.  $82^\circ 00' 16'' = 75^\circ + 7^\circ 00' 16''$ , =  $5^h 28^m 01^s$  west of Greenwich, =  $28^m 01^s$  west of  $75^\circ$ .

	h.	m.	s.
Watch time of observation Jan. 6, 1925, a. m.-----	1	10	50
Watch slow 23 <sup>s</sup> ; correction.....			+23
Standard civil time.....	1	11	13
Correction to local meridian.....		-28	01
Local civil time.....	0	43	12
Longitude in time.....	5	28	01
Time after 0 <sup>h</sup> Greenwich.....	6	11	13
	6	11.22	
	6.187	hours	

<sup>1</sup> Commencing Jan. 1, 1925, the civil and astronomic days begin at midnight. Astronomic hours are counted from 0h at midnight to 24h the following night. Prior to 1925 the astronomic day commenced at noon 12 hours later than the civil day.

	h.	m.	s.
Sidereal time 0 <sup>h</sup> Greenwich, Jan. 6-----	7	00	13
Correction for 6.187 <sup>h</sup> = 6.187 (9.8565'')-----			+61
(Use Table III, Nautical Almanac, or p. 124 of Bulletin 650.)			
Local civil time-----	0	43	12
Sidereal time of observation or hour angle of vernal equinox-----	7	44	26
Right ascension of Polaris, upper transit at Washing- ton, Jan. 6, 1925-----	1	34	41
Hour angle of Polaris at time of observation-----	6	9	45
Hour angle in arc = $t$ (p. 125, Bull. 650) = 92° 26' 15''.			

The hour angle of Polaris can be computed with sufficient accuracy from the tables in the General Land Office ephemeris as follows:

Greenwich mean time of nearest upper culmination of Polaris, Jan. 5, 1925, p. m. (General Land Office ephemeris)-----	h.	m.	s.
	6	35	24
Reduction to longitude 82° 00' 16'' (Bull. 650, p. 126)---			-54
Local mean time of upper culmination-----	6	34	30
Local mean time of observation, Jan. 6, 1925, a. m. (1 <sup>h</sup> 11 <sup>m</sup> 13 <sup>s</sup> —28 <sup>m</sup> 1 <sup>s</sup> )-----	0	43	12
		12	
Mean time hour angle (or time interval from upper culmination to observation)-----	6	8	42
Reduction to sidereal hour angle (Bull. 650, p. 126)---		+1	1
Sidereal hour angle-----	6	9	43

The difference of 2 seconds between this and the figures obtained above for the hour angle is the result of the dropping of decimals in the General Land Office tables.

The following are the formulas for azimuth and level correction:

$$\tan A = -\frac{\alpha \sin t}{1-b \cos t} \quad \alpha = \sec \phi \cot \delta \quad b = \tan \phi \cot \delta$$

$$\text{Level correction} = -\frac{d}{4} \left[ (w+w') - (e+e') \right] \tan h.$$

in which, for the example above given,

$\phi$  = latitude of station (37° 28' 47'').

$A$  = azimuth of Polaris at time of observation.

$\delta$  = declination of Polaris at time of observation (88° 54' 24'').

$t$  = hour angle of Polaris at time of observation (92° 26' 15'') (the cosine is negative, sine plus in this example), value of one division of level (2.0'').

$w, w'$  = readings of west end of level bubble, direct and reversed.

$e, e'$  = readings of east end of level bubble, direct and reversed.

$h$  = angular elevation of star (at elongation this is equal to the latitude, nearly).

The level correction is used as a correction to azimuth  $A$  only.



Each azimuth computation should be made in a single column and for convenience the columns should be placed side by side in tabular form.

The following is the computation of this observation:

Level correction = $\frac{2}{4}(2 \times 0.77) = 0.77''$			
Log tan $\phi$ (37° 28' 47'')	-----	9. 88466	
Log cot $\delta$ (88 54 24 )	-----	8. 28068	
Log cos $t$ (92 26 15 )	-----	8. 62869	(negative)
Log $b$ cos $t$	-----	6. 79403	(negative)
$b$ cos $t$	-----	-0. 000622	
		1	
1- $b$ cos $t$	-----	1. 000622	
Log sec $\phi$ (37° 28' 47'')	-----	0. 10042	
Log cot $\delta$ (88 54 24 )	-----	8. 28068	
Log sin $t$ (92 26 15 )	-----	9. 99961	(positive)
Log $a$ sin $t$	-----	8. 38071	(positive)
Log (1- $b$ cos $t$ )	-----	0. 00026	(positive)
Log tan $A$	-----	-8. 38045	
<hr/>			
$A$ (the minus sign indicates that the star was	°	'	''
west of north)	-1	22	32. 1
Level correction			+0. 8
	-1	22	32. 9
Add algebraically to 180° to refer to the			
south			180
Angle from star to mark		64	18 31
Azimuth of mark		242	55 58. 1

#### TABULATION OF TRIANGLES

By an inspection of the field plat of the triangulation determine what groups of triangles are so interrelated that a change in one will affect the others and what groups of triangles should be adjusted as a unit. For the triangulation by the Geological Survey, which is not executed for geodetic purposes, it is not advisable to include more than fifteen or twenty triangles in such a group, because the labor of solving equations for the adjustment of any group increases rapidly with its size. Four overlapping triangles form one of the simplest groups that may be adjusted by the usual least-square methods.

Assume the group shown in Figure 1 for adjustment. Tabulate the angles for each triangle, as shown at (a), (b), (c), and (d) (p. 72). Any angle in any of these triangles may be considered as the difference between the azimuths (directions) of its two sides. For

example, angle Dick-Elk-Taylor, or 4.3.1, as designated for convenience by the figures assigned to each angle vertex, would be the azimuth or direction of the line 4.3 subtracted from the azimuth or direction of the line 1-3. Azimuths are always measured in a clockwise direction. Therefore this angle may be indicated as  $-4.3 + 1.3$

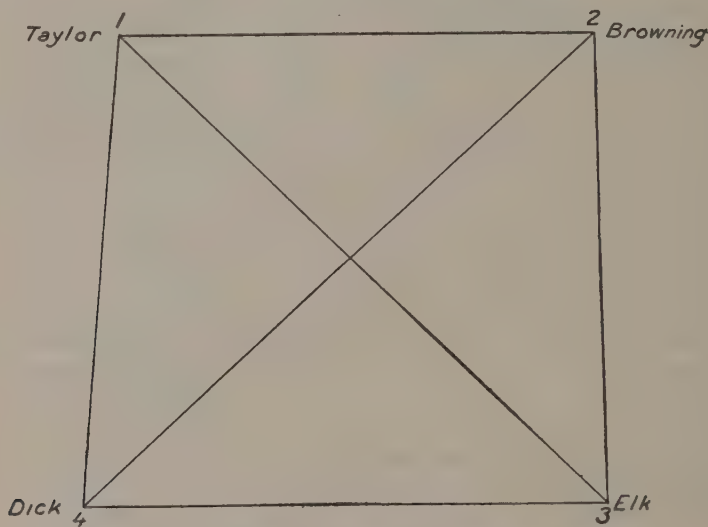


FIGURE 1.—Quadrilateral for adjustment by least-square method

or  $-4/3 + 1/3$ . In the latter form the denominator is always the figure at the vertex of the angle, and with the vertex pointing toward the observer the left-hand direction is always given the minus sign. (Directions will hereafter be referred to as sides.)

### COMPUTATION OF SPHERICAL EXCESS

For any triangle on the earth's surface the sum of the three angles, if correctly measured, will exceed  $180^\circ$  by an amount varying with the area. For use in computing distances the observed angles must be reduced to their plane values by deducting one-third the spherical excess from each. The spherical excess for any triangle between latitude  $25^\circ$  and  $45^\circ$  is approximately 1 second for each 75.5 square miles of area, or exactly equals in seconds  $abm \sin C$ , in which  $a$ ,  $b$ , and  $C$  are, respectively, the lengths of the two sides in meters and the included angle of any triangle, and  $m$  is a constant depending on the latitude.<sup>2</sup>

In computing spherical excesses for any figure (as fig. 1, for example) arrange the work systematically, the logarithms of each of two

<sup>2</sup> Logarithms of  $m$  are given in Geographic tables and formulas, U. S. Geol. Survey Bull. 650, p. 294, 1918. Between latitudes  $30^\circ$  and  $50^\circ$   $\log m$  may be found with sufficient accuracy for preliminary computations from the formula  $1.4040 + (45^\circ - \phi)$ , used as a unit in the fourth decimal place). For example: Lat.  $37^\circ$ ,  $45 - \phi = 8$ ,  $m = 1.4048$  (tabular value = 1.40482); lat.  $49^\circ$ ,  $45 - \phi = -4$ ,  $m = 1.4036$  (tabular value = 1.40359).

sides in meters from a preliminary computation, the logarithm of the sine of their included angle, and the logarithm of  $m$  for the mean latitude for each triangle; place in a column. Give the figures for the triangle at the head of the column, as 4.3.1, using the angle 4.3.1 and the sides 4-3 and 1-3 in the computation.

*Computation for spherical excess*

Triangle	4.3.1	1.3.2
Log side $a$ .....	4.29846	4.40804
Log side $b$ .....	4.40804	4.25219
Log sin $C$ .....	9.85406	9.81304
Log $m$ .....	1.40475	1.40475
Log spherical excess .....	9.96531	9.87802
Spherical excess in seconds .....	0.92	0.76

Mean latitude,  $37^{\circ} 35'$ .

In the same manner compute the spherical excess for each of the remaining triangles. Many such computations can be conveniently made in the book (9-901) used for preliminary distances, in the left-hand column adjacent to each triangle.

As the spherical excess for a given area is constant, the sum of the spherical excesses for the triangles 1.3.2 and 4.3.1 must equal the spherical excesses for the other two. This check should always be applied to the results.

### LEAST-SQUARE ADJUSTMENT

By the least-square adjustment of a triangulation net, the most probable values are found from the more or less discordant measurements. These will not necessarily be the true values but they will be such as to produce consistent results. A line or position computed from them will be the same even if computed from different sets of triangles.

After deducting the spherical excesses from the sums of angles for each triangle ( $a$ ), ( $b$ ), ( $c$ ), ( $d$ ) (see below), the differences between the remainders and  $180^{\circ}$  will be the errors, plus for remainders over  $180^{\circ}$  and minus for those less than  $180^{\circ}$ .

The algebraic sum of the closing errors of two of the triangles (of any quadrilateral) should equal the algebraic sum of the closing errors of the other two which cover the same area:

$$\begin{array}{rcl}
 -3.45 & +2.74 & \\
 +4.70 & -1.49 & \\
 \hline
 +1.25 & +1.25 & 
 \end{array}$$

This check should always be applied.



The rules for determining the number of angle equations and the number of sine or side equations required for the proper adjustment of any figure are these:

$L - S + 1 = \text{angle equations.}$

$L - 2S + 3 = \text{side equations.}$

where  $L$  equals the number of lines in the figure observed in both directions and  $S$  the number of stations. A solution of these equations for a quadrilateral shows that three angle equations and one side equation are required. In selecting the equations for a large group of triangles, it is well to consider each part of the figure in detail, commencing with three stations, adding stations with the lines to them one at a time, and at each step computing the angle and side equations required.

The side equation in a quadrilateral fixes the condition that three lines shall meet in one point.

In the present example it is immaterial which three of the four triangles are used for the adjustment.

*Angle equations*

Stations	Side	Observed angle	Correc- tion	Corrected spherical angle
		° ' "	"	° ' "
(a) { Elk ----- Taylor ----- Browning -----	-1/3+2/3	40 33 19.17	+2.13	40 33 21.30
	-2/1+3/1	44 03 30.52	+0.61	44 03 31.13
	-3/2+1/2	95 23 07.62	+0.71	95 23 08.33
		179 59 57.31		180 00 00.76
		Spherical excess. 0.76		-0.76
		Error ----- -3.45		
(b) { Dick ----- Taylor ----- Browning -----	-1/4+2/4	40 09 14.16	-0.90	40 09 13.26
	-2/1+4/1	94 38 08.09	+0.21	94 38 08.30
	-4/2+1/2	45 12 37.04	+2.18	45 12 39.22
		179 59 59.29		180 00 00.78
		Spherical excess. 0.78		-0.78
		Error ----- -1.49		
(c) { Elk ----- Dick ----- Taylor -----	-4/3+1/3	45 36 34.90	-2.97	45 36 31.93
	-1/4+3/4	83 48 53.15	-1.33	83 48 51.82
	-3/1+4/1	50 34 37.67	-0.40	50 34 37.17
		180 00 05.62		180 00 00.92
		Spherical excess. 0.92		-0.92
		Error ----- +4.70		
(d) { Elk ----- Dick ----- Browning -----	-4/3+2/3	86 09 54.07	-0.84	86 09 53.23
	-2/4+3/4	43 39 38.99	-0.43	43 39 38.56
	-3/2+4/2	50 10 30.58	-1.47	50 10 29.11
		180 00 03.64		180 00 00.90
		Spherical excess. 0.90		-0.90
		Error ----- +2.74		

To select the sines for the side equation: Consider the figure as a pyramid with vertex (the pole) at 1; by redrawing the figure with the line 4-2 dotted and the triangle 1-3-4 shaded, it will appear to the eye as such a pyramid. Select for the first set of angles for the side equations those opening to the front in going around the base of the pyramid from 2 to 3 to 4 to 2; for future reference mark them with solid

arcs of circles; the remaining angles around the base make up the other set and may be marked with dotted arcs. The pole should be selected so that the two smallest angles will be used in the equations. Find the sines for each set of angles, recording also the differences for 1'' for each; call the first set of sines plus and the second set minus, find the difference between them, and give it the sign of the greater.

*Side equations*

Sides	Observed angles	Log. sines	Difference for 1''	Correction in seconds	Correction to sines	Corrected sines
(e)	° ' "					
	$\left\{ \begin{array}{l} -1/4+3/4 \\ -4/2+1/2 \\ -1/3+2/3 \end{array} \right.$	83 48 53.15 45 12 37.04 40 33 19.17	9.9974645 9.8510731 9.8130350	+2.2 +20.9 +24.6	-1.33 +2.18 +2.12	-3 +46 +52
		9.6615726				9.9974642 9.8510777 9.8130402
						9.6615821
	$\left\{ \begin{array}{l} -1/4+2/4 \\ -3/2+1/2 \\ -4/3+1/3 \end{array} \right.$	40 09 14.16 95 23 07.62 45 36 34.90	9.8094543 9.9980787 9.8540576	+24.9 -2.0 +20.6	-0.91 +0.71 -2.97	-23 -1 -61
		9.6615906 9.6615726				9.8094520 9.9980786 9.8540515
						9.6615821 9.6615821
		-180				0

Equations of condition are now made up as follows: For triangle (a), equation (f), error equals  $-3.45''$ ; this is made up of the errors in the azimuth or direction of the sides  $-1/4+3/4-4/2+1/2-1/3+2/3$ , six in all. In like manner form equations (g) and (h). The side equation (i) is made up as follows: The error of the sines, being the difference between the two sets, is  $-180$ . To correct the sines changes in seconds to be found for the angles must be multiplied by the differences for 1 second in column 4 of (e) for the given angle; hence for the first sine this will be  $+2.2$  multiplied by the corrections to be given the directions  $-1/4$  and  $+3/4$ , or if expressed in a simple form it will be  $-2.2 \ 1/4+2.2 \ 3/4$ . Treat each side and difference for 1 second in like manner, noting, however, that for the second set of sines, which is considered negative, each sign given for the side will be reversed—for example, the first pair is written  $+24.9 \ 1/4-24.9 \ 2/4$ . It will be noticed that in the first form of (i) as written,  $1/2$  appears twice with like signs,  $1/4$  appears twice with unlike signs; combine like terms algebraically, thus reducing the equations to the second form of (i). For the convenience of the computer and in order to avoid the handling of large numbers, equation (i) has been divided through by 100, which is equivalent to taking as the unit the fifth place of decimals of the logarithms.

$$(f) \ 0 = -3.45 - 1/3 + 2/3 - 2/1 + 3/1 - 3/2 + 1/2.$$

$$(g) \ 0 = -1.49 - 1/4 + 2/4 - 2/1 + 4/1 - 4/2 + 1/2.$$

$$(h) \ 0 = +4.70 - 4/3 + 1/3 - 1/4 + 3/4 - 3/1 + 4/1.$$

$$(i) \ 0 = -1.80 - 0.022 \ 1/4 + 0.022 \ 3/4 - 0.209 \ 4/2 + 0.209 \ 1/2 - 0.246 \ 1/3 + 0.246 \ 2/3 \\ - (-0.249 \ 1/4 + 0.249 \ 2/4 + 0.020 \ 3/2 - 0.020 \ 1/2 - 0.206 \ 4/3 + 0.206 \ 1/3).$$

Combining like terms and changing all signs within the parentheses reduces equation (i) to the following form:

$$(i) \ 0 = -1.80 + 0.227 \frac{1}{4} + 0.022 \frac{3}{4} - 0.209 \frac{4}{2} + 0.229 \frac{1}{2} - 0.452 \frac{1}{3} + 0.246 \frac{2}{3} - 0.249 \frac{2}{4} - 0.020 \frac{3}{2} + 0.206 \frac{4}{3}.$$

There are now four equations to be solved and 12 unknown quantities; the latter are combined and reduced to four by means of correlates. In the following table column (j) contains the designations of the sides or directions for which corrections are required. Column (k) contains on the proper lines the algebraic coefficients for the sides from equation (f); for example,  $-1/3$ , considered as a quantity, might be written  $-1(1/3)$ , and  $+2/3$  in like manner written  $+1(2/3)$ ;  $-1$  and  $+1$  are therefore the entries for column (k), lines  $1/3$  and  $2/3$ .

*Correlates*

(j)	(k)	(l)	(m)	(n)	Correlates after substituting values				Corrections	Sides
Sides	1	2	3	4	1 -0.314	2 +0.590	3 -0.651	4 +3.010		
2/1	-1	-1	-----	-----	+0.314	-0.590	-----	-----	-0.276	2/1
3/1	1	-----	-1	-----	-0.314	-----	-----	-----	+0.337	3/1
4/1	-----	1	1	-----	-----	+0.590	+0.651	-----	-0.061	4/1
1/2	1	1	-----	+0.229	-0.314	+0.590	-0.651	-----	+0.965	1/2
3/2	-1	-----	-----	-0.020	+0.314	-----	-----	+0.689	-0.060	3/2
4/2	-----	-1	-----	-0.209	-----	-0.590	-----	-0.629	-1.219	4/2
1/3	-1	-----	1	-0.452	+0.314	-----	-----	-1.361	-1.698	1/3
2/3	1	-----	-----	+0.246	-0.314	-----	-0.651	+0.740	+0.426	2/3
4/3	-----	-----	-1	+0.206	-----	-----	-----	+0.620	+1.271	4/3
1/4	-----	-1	-1	+0.227	-----	-0.590	+0.651	+0.683	+0.744	1/4
2/4	-----	1	-----	-0.249	-----	+0.590	-----	-0.749	-0.159	2/4
3/4	-----	-----	1	+0.022	-----	-----	-0.651	+0.066	-0.585	3/4

Normal equations are formed from the table of correlates as follows: Column 1, line 1, of (o) (p. 75) contains the sum of the squares of each quantity in column (k). Column 2, lines 1 and 2, contains, first, the sum of the products of each quantity in column (k) by corresponding quantities in column (l); second, the sum of the squares of each quantity in column (l). Column 3, lines 1, 2, and 3, contains the sum of the products of (k) by (m), (l) by (m), and (m) by (m) (the squares). Column 4 is made up in the same manner, using the quantities and signs as given. If columns 1, 2, and 3 are completely filled out by products found as indicated above, it will be found that the quantities from +6.000 down the column are the same as those from +6.000 along the lines to the right to column 4. But as the former are not needed in the solution they may be omitted; when retained, the equations in full will be as follows, the second member of each equation being zero:

## (o) Normal equations

1	2	3	4	Absolute term
+6.000	+2.000	-2.000	+0.947	-3.450
+2.000	+6.000	+2.000	-.038	-1.490
-2.000	+2.000	+6.000	-.863	+4.700
+0.947	-0.038	-0.863	+5.1779	-1.800

These are ordinary algebraic equations which may be solved by the usual rules of algebra, but, as the solution of 10, 15, or more equations is often required in Geological Survey work, the process should be conducted systematically as shown.

*Solution of normal equations*

(p)

	1	2	3	4	Absolute term
(p <sub>1</sub> )	+6.000	+2.000	-2.000	+0.9470	-3.450
(p <sub>2</sub> )	(-1.1667)	-.333	+.333	-.1578	+.575
(p <sub>3</sub> )		+5.333	+2.667	-.3537	-.340
(p <sub>4</sub> )	-----	(-1.1875)	-.500	+.0663	+.064
(p <sub>5</sub> )	-----		+4.000	-.3705	+3.720
(p <sub>6</sub> )	-----		(-1.250)	+.0926	-.930
(p <sub>7</sub> )	-----			+.31060	-.935
(p <sub>8</sub> )	-----			(-3.2196)	+3.010

(q)

	2	3	4	Absolute term
(q <sub>1</sub> )	+6.000	+2.000	-0.0380	-1.490
(q <sub>2</sub> )	-.667	+.667	-.3157	+1.150
(q <sub>3</sub> )	-----	+6.000	-.8630	+4.700
(q <sub>4</sub> )	-----	-.667	+.3157	-1.150
(q <sub>5</sub> )	-----	-1.333	+.1768	+.170
(q <sub>6</sub> )	-----		+.51779	-1.800
(q <sub>7</sub> )	-----		-.149447	+.544
(q <sub>8</sub> )	-----		-.023450	-.023
(q <sub>9</sub> )	-----		-.034318	+.344

(r)

	1	2	3	4
(r <sub>1</sub> )	+0.575	+0.064	-0.930	+3.010
(r <sub>2</sub> )	-.475	+.200	+.279	
(r <sub>3</sub> )	-.217	+.326	- .651	
(r <sub>4</sub> )	-.197	+.590		
(r <sub>5</sub> )	-.314			



The first normal equation is written in full on line ( $p_1$ ); parts of the other equations are written on lines ( $q_1$ ), ( $q_3$ ), and ( $q_6$ ). The reciprocal from Barlow's tables of the first quantity (+6.000, line ( $p_1$ ), column 1), is placed in parentheses, line ( $p_2$ ). The product of this reciprocal (0.1667) by the quantities on line ( $p_1$ ), columns 2, 3, and 4, and absolute are written immediately under each in turn; the quantity +0.333 (line ( $p_2$ ), column 2) is now used as a multiplier for line ( $p_1$ ) (omitting column 1), and the products are placed in columns 2, 3, 4, and absolute, line ( $q_2$ ); in like manner the quantities -0.333 (line ( $p_2$ ), column 3) and -0.1578 (column 4) are used as multipliers and the products written on lines ( $q_4$ ) and ( $q_7$ ). The algebraic sums of lines ( $q_1$ ) and ( $q_2$ ) are now written on line ( $p_3$ ), which is then used as if it were an original equation. The reciprocal of +5.333 is found and used as a multiplier as before, and the products are written on line ( $p_4$ ). The next products are written on lines ( $q_5$ ) and ( $q_8$ ). The sums of each column of lines ( $q_3$ ), ( $q_4$ ), and ( $q_5$ ) is carried over to ( $p_5$ ). The process is repeated for each equation until finally the product +3.010 is found, which is the value for unknown quantity numbered 4. This value and also the quantities in the column of absolute terms, lines ( $p_6$ ), ( $p_4$ ), and ( $p_5$ ), are copied in the table (r), line ( $r_1$ ). With +3.010 as a multiplier products of each quantity in column 4, lines ( $p_6$ ), ( $p_4$ ), and ( $p_2$ ), are found and written on line ( $r_2$ ), columns 3, 2, and 1. Column 3 or (r) is then summed and the result (-0.651) is the value of unknown quantity numbered 3. This is used as a multiplier and products found with quantities from columns 3 and 2, lines ( $p_4$ ) and ( $p_2$ ), and in like manner values for unknown quantities numbered 2 and 1 are found.

The solution of the normal equations and the values found for the unknown quantities may be checked by substituting in the full equations (p. 75).

The next step in the adjustment is to substitute the values for the four unknown quantities in the table of correlates (p. 74) and to find the correction for each side. The method of doing this can be easily seen by following the process through the right-hand half of that table. For convenience, the value found for each unknown quantity is written at the head of columns 1, 2, 3, and 4. Each of these in turn is multiplied by quantities in columns 1, 2, 3, and 4 of the left-hand part of the table and the products are placed in the right-hand part on the same line with the multiplicand. The final correction for any side is then the algebraic sum of the quantities, which are on line with the side number in columns 1, 2, 3, and 4 (at the right side of the table). Thus the correction 2/1 is made up of +0.314 - 0.590 = -0.276; this is the correction in seconds to the side. The correction for any angle, then, is the difference between the cor-

rections for the two sides bounding it. For example: Angle at Elk, triangle (a), is:

$$\begin{array}{r} -\text{correction } 1/3 = +1.698 \\ +\text{correction } 2/3 = +.426 \\ \hline +2.124 \end{array}$$

The correction for any sine is the correction for the corresponding angle multiplied by the difference for 1'' in the sine.

It is desirable to have triangles close without errors greater than a tenth of a second and to have side equations close to the sixth place of the logarithm, but unless the normal equations are carried to three or four decimal places there will possibly be residual errors of two or three hundredths in some triangle closures. It is, however, considered allowable in Geological Survey work to make arbitrary changes of not over  $\pm 0.03''$  in angles in order to obtain consistent results.

The figures for adjustment will generally be larger than quadrilaterals, though they may be made up of quadrilaterals or triangles which do not overlap and are therefore independent each of the other. When they do overlap select for the first pyramid group (p. 70) the one which takes in the largest number of triangles and set down (according to the formula on p. 72) the number of triangle equations required to adjust it completely, remembering that the triangles used must always cover the whole area once but not twice. For the second group set down the number of triangle equations required by the rule as if they were from an independent pyramid group, but omit from those selected all which would be adjusted in or by the first group, the vertex of the pyramid being so situated that a base triangle will not be included in a former group. In other words, as group by group is added to the first find for each a single side equation and as many additional angle equations as are required, including in the number all triangles adjusted by a previous group excluding those which appear in each or which would appear in each if the vertex of the pyramid were taken in a different place.

In any figure in which each station is sighted from every other one no attention need be paid to the selection of triangles for use in the adjustment; they may be taken at random, provided the number required by the formula is used.

In order to adjust an extensive triangulation scheme, the strongest groups are adjusted first; then if lines or triangles in them form parts of other groups, their first adjusted values are given infinite weights and thus left unchanged.

In connecting new groups of triangles with those previously adjusted, if more than a single adjusted line is used a condition must be introduced fixing the relative length of the adjusted lines. For

example: Let the solid lines in Figure 2 represent an adjusted group and the dotted lines part of a new group of triangles to be adjusted. It is evident that the distance  $ac$  and the angle  $abc$  are fixed by the completed adjustment; therefore in adjusting the new work a side equation must be used in order to maintain the relative length of the lines  $ab$  and  $bc$ . This may be taken from the quadrilateral  $adce$  with the central point  $b$ , infinite weight being given to the five adjusted lines.

The accuracy of figure adjustments will be increased if the sines of the smallest angles are used in forming the equations and if each

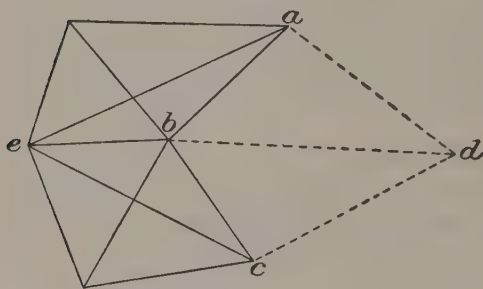


FIGURE 2.—Condition to be introduced in connecting new triangles to those previously adjusted

figure used covers the largest possible area; but on the other hand labor will be saved if as few angles as possible are involved. These conditions appear when two figures overlap; in such cases a sum angle can be used in adjusting one figure, with a saving of labor, but unless all the triangles are of good shape it is better to

take the triangles which cover the largest area. Whether the slight increase in accuracy justifies the extra labor involved depends on the quality of the work.

The angles to be used depend on the position taken for the pole of the assumed pyramid.

### WEIGHTED OBSERVATIONS

If the field notes show that certain angle measures are incomplete or uncertain it is generally advisable to introduce weights. These may be in the form of fractions or whole numbers, but in assigning them the field observations and records alone should be considered, not triangle closures. An infinite weight is given when it is desired to hold the value for a direction, as when it is taken from a previously adjusted figure. A weight of  $\infty$  for a side reduces all correlatable products for it to 0—in other words, eliminates its effect on the normal equations.

Weights are used only in the table of correlates on page 79. As an example of their use let weights be assumed for directions in the table of correlates as follows:

The rule for forming normal equations from weighted correlates is that each product for a given side is to be divided by the weight for that side before combining it to form a term in the equation.

For example: The first term in equation 1 is made up as follows from column t of the correlates:

$$\begin{aligned}
 \text{Side 2/1 } (-1) (-1) \div \text{weight 2} &= +0.500 \\
 \text{Side 3/1 } (+1) (+1) \div \text{weight 1} &= +1.000 \\
 \text{Side 1/2 } (+1) (+1) \div \text{weight 2} &= +0.500 \\
 \text{Side 3/2 } (-1) (-1) \div \text{weight 3} &= +0.333 \\
 \text{Side 1/3 } (-1) (-1) \div \text{weight 1} &= +1.000 \\
 \text{Side 2/3 } (+1) (+1) \div \text{weight } \frac{1}{2} &= +2.000 \\
 \hline
 &+5.333
 \end{aligned}$$

The sum of these quantities, +5.333, is the coefficient of the first term. The fourth term of equation 1 is

$$\begin{aligned}
 \text{Side 1/2 } (+1) (+0.229) \div \text{weight 2} &= +0.1145 \\
 \text{Side 3/2 } (-1) (-0.020) \div \text{weight 3} &= +0.0067 \\
 \text{Side 1/3 } (-1) (-0.452) \div \text{weight 1} &= +0.4520 \\
 \text{Side 2/3 } (+1) (+0.246) \div \text{weight } \frac{1}{2} &= +0.4920 \\
 \hline
 &+1.0652
 \end{aligned}$$

Combining these quantities gives +1.0652, which is the coefficient of the term desired. Each other term of the normal equation is found in a similar manner.

These equations after solving by the usual methods give the values at the head of columns 1, 2, 3, and 4 in the right-hand part of the following table of correlates. These values after multiplying by the quantities in columns t, u, v, and w are placed in their appropriate spaces and the sum for each line found as described on page 76. Each sum thus found for a side is then divided by the weight for the side, the quotient being the correction for the side, and the corrections thus found, if applied to the triangles (p. 72) and the side equation (p. 75), will make a complete adjustment for the figure.

*Correlates for weighted equations*

Sides	Weights	t	u	v	w	1 (-0.415)	2 (+0.703)	3 (-0.756)	4 (+3.236)	Sums	Sums divided by weights
		1	2	3	4						
2/1	2	-1	-1			+0.415	-0.703			-0.288	-0.144
3/1	1	1		-1		-.415		+0.756		+ .341	+ .341
4/1	1		1	1			+ .703	-.756		- .053	- .053
1/2	2	1	1		+0.229	-.415	+ .703		+0.741	+1.029	+ .514
3/2	3	-1			-.020	+ .415			-.065	+ .350	+ .117
4/2	1		-1		-.209		-.703		-.676	-1.379	-1.379
1/3	1	-1		1	-.452	+ .415		-.756	-1.463	-1.804	-1.804
2/3	$\frac{1}{2}$	1			+ .246	-.415			+ .797	+ .382	+ .764
4/3	1			-1	+ .206			+ .756	+ .666	+1.422	+1.422
1/4	2		-1	-1	+ .227		-.703	+ .756	+ .735	+ .788	+ .394
2/4	1		1		-.249		+ .703		-.806	- .103	- .103
3/4	1			1	+ .022			-.756	+ .071	- .685	- .685



*Normal equations*

1	2	3	4	Absolute
+5.333	+1.000	-2.000	+1.0652	-3.450
+1.000	+4.500	+1.500	-.039	-1.490
-2.000	+1.500	+5.500	-.750	+4.700
+1.0652	-.039	-.750	+5.526055	-1.800

In the solutions of the normal equations on page 75 no method was shown for checking the work before the final values of the unknown had been found and substituted in the full equations. There is a simple method for checking a solution frequently, and as it involves but little extra labor it should be adopted when a large number of simultaneous equations are to be solved. The check requires an added term for each equation, the numerical value of which is the algebraic sum of all the coefficients and the absolute term of each full normal equation. The check numbers should be given a sign opposite to that of the sum, so that the equations will still have the form of  $(a) + (b) + \text{etc.} = 0$ .

In the following solution the check is used; the solution differs slightly in form of arrangement from that shown on page 75 and is in some respects simpler.

The check column is numbered 6; the first term, line (a), is the algebraic sum of each quantity on line (a) with the opposite sign; similarly lines (c), (g), and (l) contain check numbers found from the sum of the quantities in each of the full equations; but as all the terms of each equation are not written down they may be found, because of the symmetry of the equations, from quantities given in other equations. For example, for equation 3 add together the quantities in column 3 of the normal equations (p. 75) and those on the third line:  $-2.000 + 1.500 + 5.500 - 0.750 + 4.700 = 8.950$ ; hence  $-8.950$  is the check number. The check numbers are to be treated in the solution as if they were absolute quantities.

For the first equation the reciprocal of the first coefficient (5.333) with its sign changed is  $-0.1875$ ; this multiplied by each term of line (a) gives the quantities in line (b).

The quantity  $-0.1875$  (column 2, line b) is next taken as a multiplier for all the coefficients immediately above it and for others to the right on line (a), the products being written on line (d).

*Solution of equations, with check*

Reciprocals	1	2	3	4	5 (absolute)	6 (check)	
-0. 1875	+5. 333 -1.	+1. 000	-2. 000	+1. 0652	-3. 450	-1. 948	(a)
		-1. 1875	+1. 375	-1. 1997	+1. 647	+1. 365	(b)
		+4. 500	+1. 500	-1. 0390	-1. 490	-5. 471	(c)
		-1. 187	+1. 375	-1. 1997	+1. 647	+1. 365	(d)
-0. 2319	-----	+4. 313	+1. 875	-1. 2387	-1. 943	-5. 106	(e)
		-1.	-1. 435	+1. 0554	+1. 195	+1. 184	(f)
			+5. 500	-1. 7500	+4. 700	-8. 950	(g)
			-1. 750	+1. 3995	-1. 294	-1. 730	(h)
-0. 2542	-----		-1. 816	+1. 1038	+1. 367	+2. 221	(i)
			+3. 984	-1. 2467	+3. 773	-7. 459	(j)
			-1.	+1. 0627	-1. 959	+1. 896	(k)
				+1. 526055	-1. 800	+1. 998	(l)
-3. 5132	-----			-1. 212720	+1. 689	+1. 389	(m)
				-1. 013224	-1. 047	-1. 283	(n)
				-1. 015468	+1. 236	-1. 468	(o)
				+1. 284643	-1. 921	+1. 636	(p)
				-1.	+3. 236	-2. 235	(q)
	+1. 647	+1. 195	-1. 959	+3. 236			(r)
	-1. 646	+1. 179	+1. 203				(s)
	-1. 284	+1. 329					(t)
			-1. 756				
	-1. 132	+1. 703					(u)
	-1. 415						(v)

Products for equation 3, written on line (h), are found with the multiplier +0.375 and the quantities in columns 3, 4, 5, and 6, line (a). All the other numbers on line (b) for any set of equations except those in the absolute column 5 and the check column 6, are used as multipliers, and the products are written under the equations to which they belong. Lines (c) and (d) are next added algebraically and the sums written on line (e).

Line (e) now consists of a complete equation containing but three unknown quantities, an absolute term, and a check term, and the algebraic sum of all the quantities on the line should be zero, reasonable allowance being made for slight errors introduced from the dropping of decimal places beyond the fourth. This constitutes the first useful application of the check term.

The reciprocal of the first term in line (e) with sign changed is -0.2319; this multiplied by each quantity in line (e) gives the products on line (f); these also if combined algebraically should equal zero, and thus the work is again checked.

Products from multipliers for each unknown quantity (-0.435 and +0.0554) are next found in the same manner as for lines (a) and (b) and written under the equations to which they belong (on lines (i) and (m) in this example). The algebraic sum of each column under equation 3 is next to be found and written on line (j). This is now a complete equation with two unknown quantities, and the sum for the whole line should equal 0, this being the third use of the check

term. This elimination process is repeated and the check applied until line (q) is reached, the absolute term then being the value of the fourth unknown. This value is written on line (r), column 4, and the absolute quantities from column 5, lines (k), (f), and (b), are written in columns 3, 2, and 1, line (r). The numerical value of number 4 is next to be multiplied by the coefficients of number 4 in column 4, lines (k), (f), and (b), and the products written on line (s), columns 3, 2, and 1, respectively. The sum of the quantities in lines (r) and (s), column 3, is  $-0.7560$ , which is the value found for unknown number 3, and this value substituted in column 3 gives products for line (s).

### ADJUSTING LINES TO UNOCCUPIED STATIONS

An adjustment can be made for the three lines to an unoccupied station as follows: Correct the observed angles to the unoccupied point to agree with previously adjusted angles at each occupied station; then form a side equation, making the unoccupied station the pole of the pyramid, if thereby the small angles are used in making up the equations.

The swings for the lines to the unoccupied station, which will be the corrections desired, will be the products of the sine differences for  $1''$  (coefficients of the sine equation) by the absolute term, divided by the sum of the squares of the former.

For each additional line more than three to the unoccupied station an additional side equation is required, all to be solved in the usual manner.

### COMPUTATION OF DISTANCE

The computations of distance are to be made in book 9-901. The triangles are arranged in order from a given base or known side, one page or part of a page being taken for each new station. For each triangle the adjusted spherical angles and the spherical excess are given to hundredths of seconds.

#### *Example of computation of distance*

Station	Spherical angle	Spherical excess	Plane angle (9.8853615)	Log sines and distances
	° ' "		° ' "	
Browning.....	50 10 29.11	-0.30	50 10 28.81	4.2984616
Elk.....	86 09 53.23	-.30	86 09 52.93	0.1146385
Dick.....	43 39 38.56	-.30	43 39 38.26	9.9990263
	180 00 00.90		180 00 00.00	9.8390917
Miles, 11.106.....			Browning to Elk.	4.2521918
Miles, 16.050.....			Browning to Dick.	4.4121264

After adjustment of several overlapping figures has been completed, it is occasionally necessary to find the length of some line joining two points which has not been included in the adjustment. Such lines may usually be computed by the formula for "two sides and the included angle."<sup>3</sup>

The rule for the solution of plane triangles for which the three angles and one side are given is that the sides are proportional to the sines of the opposite angles. By always arranging the angles in the form above suggested, with the new station first, the solution is made somewhat mechanical. The logarithms of the sines of plane angles are used; that for the angle at the new station from which distances are required to the other two stations is written immediately above the angle; its arithmetical complement (10 minus the sine) is written to the right and on line with the angle. Each of the other sines is placed on line with the angle to which it relates. Immediately above the sines is written the logarithm of the distance in meters<sup>4</sup> between the second and third stations in the triangle; in the example this is 4.2984616 for the line Elk to Dick.

To get the logarithm of the distance from the new station (Browning in the example) to one of the other stations, omit the sine opposite the latter and add together the remaining logarithms in the right-hand column. The distance to thousandths of a mile for each computed line must be found and placed to the left of the names of the terminal stations. The work should be verified by comparing distances for each line that has been computed from two or more triangles.

#### COMPUTATION OF GEODETIC COORDINATES

For the computation of geodetic coordinates use book 9-902 and check results by computing each position from two stations which form a triangle with the new station. For convenience, only one of the computations is here given:

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<sup>3</sup> U. S. Geol. Survey Bull. 650, p. 8, 1918.

<sup>4</sup> Meters are used by the Geological Survey in all triangulation computations for the reason that the best obtainable geodetic factors are those prepared by the United States Coast and Geodetic Survey, which are metric.



Azimuth <i>a</i> : <i>Elk-Dick</i> -----	96	56	01.12
Spherical angle at <i>Elk</i> -----	86	09	53.23+
Azimuth <i>a'</i> : <i>Elk-Browning</i> -----	183	05	54.35
$\Delta a + 180^\circ$ -----	180	00	24.02
Azimuth ( <i>a</i> ): <i>Browning-Elk</i> -----	3	06	18.37

## LATITUDE

## LONGITUDE

° ' "				° ' "				
$\phi$ -----	37	28	47.32	<i>Elk.</i>	$\lambda$ -----	82	00	16.16
$\Delta\phi$ -----		9	38.88(+)		$\Delta\lambda$ -----		0	39.40(-)
<hr/>				<hr/>				
$\phi$ -----	37	38	26.20	<i>Browning.</i>	$\lambda'$ -----	81	59	36.76
Computation for latitude:				Computation for longitude:				
$\log s$ -----	4.	2521918			$\log s$ -----	4.	2521918	
$\log B$ -----	8.	5110415	$\Delta$ arc and sine		$\log \sin a'$ -----	8.	7328074(-)	
$\log \cos a'$ -----	9.	9993647(-)	( $\log s$ )-----	-06	$\log A'$ -----	8.	5091777	
			( $\log V$ )-----	+00	$\log \sec \phi$ -----	0.	1013532	
$\log (I)$ -----	2.	7625980(-)		-06	$\Delta a$ and $s$ -----		(-6)	
$\log s^2$ -----	8.	50438			$\log (V)$ -----	1.	5955295(-)	
$\log C$ -----	1.	28943					39.403-	
$\log \sin^2 a'$ -----	7.	46561			$\Delta\lambda$ -----	39.	40-	
$\log (II)$ -----	7.	25942			Computation for azimuth:			
$\log D$ -----	2.	3771			$\log (V)$ -----	1.	595530(-)	
$\log [I+II]^2$ -----	5.	5252			$\log \sin\left(\frac{\phi+\phi'}{2}\right)$ -----	9.	785041	
$\log (III)$ -----	7.	9023	$\phi 37$ 28 47.3		$\log \sec\left(\frac{\Delta\phi}{2}\right)$ -----	0.	000000	
			$\phi' 37$ 38 26.2		$\log (VI)$ -----	1.	380572(-)	
$\log E$ -----	6.	0528		67 13.5	- $\Delta a$ -----	24''.	02(-)	
$\log s^2 \sin^2 a'$ -----	5.	9700			$\Delta a$ -----	24''.	02(+)	
$\log (I)$ -----	2.	7626(-)	37 33 37.0		Azimuth check.			
$\log (IV)$ -----	4.	7854(-)				° ' "		
- $IV$ -----	.000(-)				$[I+II]$	578.891	53 16 47.48	
(I)-----	578.	893(-)			$\log [I+II]$	2.762598	3 06 18.37	
(II)-----	.003+				$\log [I+II]^2$	5.525196	50 10 29.11	
(III)-----	.008+							
(IV)-----	.000(+)							
- $\Delta\phi$ -----	578.883(-)							
$\Delta\phi$ -----	9	38.88(+)						
Computation of azimuth $a$ , in book A1505, page 26.								
Spherical angle and distance $s$ , in book A1570, page 32.								

Computed by D. M. E.

[NOTE.—The signs (+) or (-) placed after logarithms are the signs of the cosines or sines of the azimuth used in the computations.]

In this example the azimuth,  $96^{\circ} 56' 01''.12$ , is derived from a previous computation. The spherical angle is that at Elk from the adjusted figure. Whether to add or subtract this can be determined very easily by inspecting a plat of the stations, but when for one of the pair of computations the spherical angle is added, the other is always subtracted. The latitude and longitude at Elk are also derived from a previous computation. Logarithm  $s$  is the logarithm of the distance in meters between Elk and Browning. The constants  $B$ ,  $C$ ,  $D$ , and  $E$  are taken from "Geographic tables and formulas"<sup>5</sup> for the known latitude at Elk. Cosine  $a'$  and sine  $a'$  are functions of the azimuth Elk to Browning. The algebraic sign of each of these functions as fixed by trigonometric rules determines the sign of the resulting quantity. The signs of (II) and (III) are always positive; that for (IV) is always opposite to that of (I). The constant  $A'$  and secant  $\phi'$  in the longitudinal computation are for the new latitude, which requires that the latitude computation be made first. These two factors will be the same for each of the pair of computations for the new position. For short lines, corrections (III) and (IV) will generally be less than  $0.01''$  and may be neglected.

When the logarithm of distance  $s$  in meters exceeds 4.0000000, a correction will usually be required for logarithm (V) for the difference between the arc and sine. The constants for computing this correction are given on page 292 of "Geographic tables and formulas,"<sup>6</sup> the arguments being log distance  $s$  and log (V). The difference between the values found is to be applied, according to the sign of the greater, to log (V) before finding the value of the latter in seconds.

Six places of decimals will usually give sufficient accuracy for log (VI). The logarithm of secant  $\left(\frac{\phi\Delta}{2}\right)$  may be taken from page 291 of "Geographic tables and formulas." When log (V) is large, say over 3.5000000, a correction in seconds<sup>6</sup> will be needed for  $\Delta a$  expressed by the factor  $(\Delta\lambda)^3 F$ . The logarithm of (V) is multiplied by 3 and added to the logarithm of  $F$ , which is given in the tables; the value in seconds for the resulting logarithm is always to be added to the previously found value in seconds for (VI).

The latitudes and longitudes for each point thus computed in pairs should agree within one or two one-hundredths of a second.

The difference between the two reverse azimuths should also agree with the corresponding adjusted spherical angle within one or two one-hundredths of a second.

The formulas for finding azimuth and distance between points whose latitude and longitude are known and the form for 3-point computations are given in "Geographic tables and formulas." Special blanks for 3-point work may be procured by application to the Washington office.

<sup>5</sup> See also Coast and Geodetic Survey Special Pub. 8, 1911.

<sup>6</sup> U. S. Geol. Survey Bull. 650, 1924.

### TABULATION OF RESULTS

The final step in the computation of triangulation is the tabulation of the results. A printed blank is used; on it is written the name of the station, the State and county in which the station is situated, the kind of signal and the center mark used, a full description of the station (see p. 62), the latitude and longitude, the azimuth, the back azimuth, and the logarithms of distances in meters and corresponding distances in miles to all other stations from which it is visible; also a statement regarding the datum on which positions are based. Whenever possible this should be the North American datum (formerly known as the United States standard datum).

### SUGGESTIONS TO COMPUTERS

Do not crowd your work; paper is comparatively cheap.

Do your work in a systematic manner. If it permits tabular arrangement, always use the forms approved by other computers unless you can convince them that yours are better. The survey has printed forms for many purposes; these should be used whenever possible, for by their use the work is made more mechanical, and the more mechanically the work is done the less chance there is for error.

A computer who is inexperienced or out of practice should check his work in every way possible. He should check logarithms either of numbers or of circular functions by using first a tabular value for a quantity less than the given one and then a greater tabular value, so that the differences in one case may be added and in the other subtracted. This operation may be reversed when the logarithm is given and numbers or angles are required.

Many errors are made by taking out the first three figures of a logarithm from the wrong line of a seven-place table where a dash over the fourth figure indicates that the first three should come from a lower line.

As the algebraic signs of cosines and sines are so frequently required, the rules governing them should be firmly fixed in the mind; as an aid to this remember the general rule that distances measured upward or to the right on the conventional plat of the quadrants of the circle are considered positive, and others negative. The wrong use of signs is a very common source of error.

Where the function of an angle over  $90^\circ$  is desired, instead of subtracting  $90^\circ$  or  $270^\circ$  from the angle to find the argument, add the figures in the tens and hundreds of degrees together and prefix the sum to the unit degree figure, dropping the sum if it is 9. Thus  $121^\circ$  gives  $1+2=3$ , and  $31^\circ$  is the argument;  $184^\circ$  gives  $1+8=9$ , drop it, leaving  $4^\circ$  for the argument;  $290^\circ$  gives  $9+2=11$ ,

drop 9 from the 11 or add the two figures a second time, giving an argument of  $20^\circ$ .

Each step in a long computation, if it is not at once automatically checked, should be checked by repeating the computation.

Check the copying of angles, distances, etc., taken from adjusted results for use in new computations; also check figures carried from page to page.

Gross errors are sometimes made by using the sine when a cosine is required, or by writing a product in the wrong column, as east for west, in primary-traverse computations.

Placing the decimal point in the wrong place is a common mistake. This may in many cases be corrected by a mere inspection of the quantity to see whether it appears of proper value.

Good judgment should be exercised in the degree of accuracy sought for a given result. For the preliminary computation of geographic positions, for example, six-place logarithms will suffice; these can be taken from a seven-place table with only a rough interpolation. A four-place logarithm can often be used to advantage. The accuracy of the results obtained should equal the requirements; more than this involves a waste of time.

The foot, yard, and mile are the units adopted for all Geological Survey field work, but for geodetic computations meters are used. The best conversion tables for metric and English measures are those published by the Bureau of Standards. In using these tables all changes from one system to another should be checked by reversing the operation. The logarithms for the interchange of these measures are given in "Geographic tables and formulas," page 364.

When computers are duplicating work and a difference is found, each should recompute the result before correcting either, as errors have frequently been made by changing the correct figures.

When two persons are comparing a copy with the original if the reader occasionally calls out a wrong figure or word intentionally and notes whether the error is caught up, it tends to keep the listener more intent on the work.





## C. TRANSIT TRAVERSE

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Compiled by E. M. DOUGLAS

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### GENERAL CONDITIONS FOR MAP CONTROL

The boundary lines of all regular United States Geological Survey maps are parallels of latitude and meridians of longitude. In order that these shall be properly located and that intermediate points shall be placed in correct positions, some system of horizontal control is required. The method to be adopted for linear control should be fixed by the character of the country, one of the requirements being that all control work shall be so accurate that no errors will be apparent in maps several times as large in scale as those to be published. In mountainous regions or in hilly, partly timbered areas horizontal control is effected by a system of triangulation, the whole area being divided up into triangles whose apexes are represented by stations established on prominent points several miles apart.

In heavily timbered areas, where it is difficult to see from any point more than a mile or two in any direction, horizontal control is best obtained from distances measured on the ground with a 300-foot steel tape, a record being made of angles measured with a transit at each bend in the line. Such control must begin and end at points whose positions have been previously determined, and regardless of the character of the country such control must be carried around the edge of each quadrangle and once across its center east and west.

The United States Board of Surveys and Maps has classified traverse control for geodetic or map use into four orders. The position check for the first order is 1 in 25,000; for the second order, 1 in 10,000; for the third order, 1 in 5,000. Control of the fourth order is based on tape, wheel, or stadia distance measurements. For transit-traverse control as executed by the Geological Survey for map use an accuracy of the third order only is necessary, but the limit of error of 1 in 5,000 must be maintained. The main or trunk-line traverses that supplement the first-order (precise) work of the United States Coast and Geodetic Survey must be of such an accuracy that a control point near the corner of each degree quadrangle shall be located with an error of not more than 1 in 7,500.

## TRANSIT-TRAVERSE FIELD WORK

### PERSONNEL AND OUTFIT OF PARTY

A transit-traverse party consists of an instrument man in charge, a recorder, two tapemen, and two rodmen; also a cook and a teamster when camping is necessary.

The following supplies (see pls. 5, 6) can be obtained on requisition:

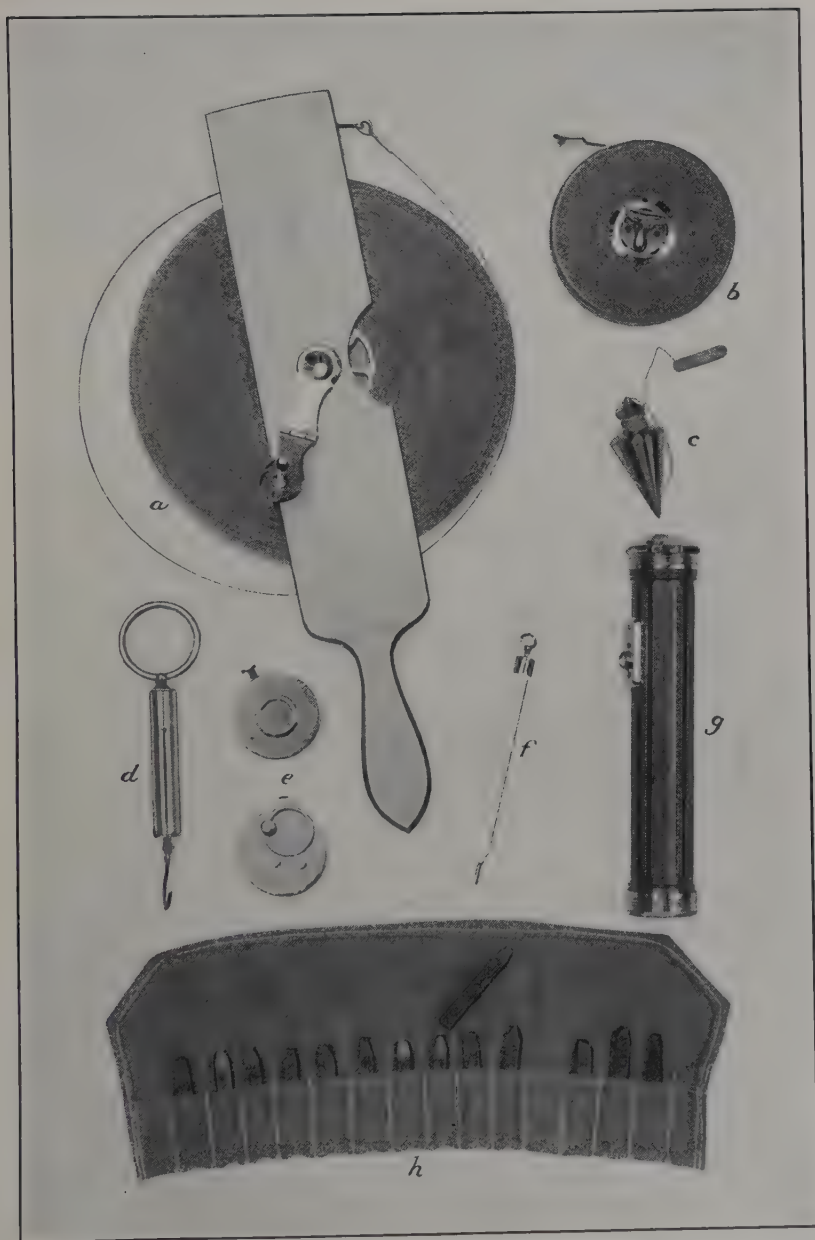
- One transit, graduated to 30 seconds and furnished with stadia wires.
- Two 300-foot steel tapes, graduated to feet throughout.
- One 100-foot steel tape.
- Two red and white transit rods.
- One stadia rod.
- Two plumb bobs.
- Eleven tally pins.
- Three hand recorders.
- Two electric hand lamps.
- One tape repair outfit, punch, and rivets.
- Three tape clips, temporary repairs.
- Two tape holders.
- One spring balance.
- One thermometer.
- One set steel dies, figures.
- One set steel dies, letters.
- Three large book bags.
- Standard bench-mark tablets.
- Canteens.
- Cement (in cans).
- Drills, hatchet, hammer, post-hole digger.
- Transit-traverse field notebooks 9-928.
- Tapemen's notebooks 9-929.
- Blank notebooks 9-896, or 3 by 5 inch pieces of manila paper.
- Book of instructions.
- Polaris and sun tables.

The instrument man must carry a reliable watch.

### ADJUSTMENT OF INSTRUMENTS

#### PRECAUTIONS

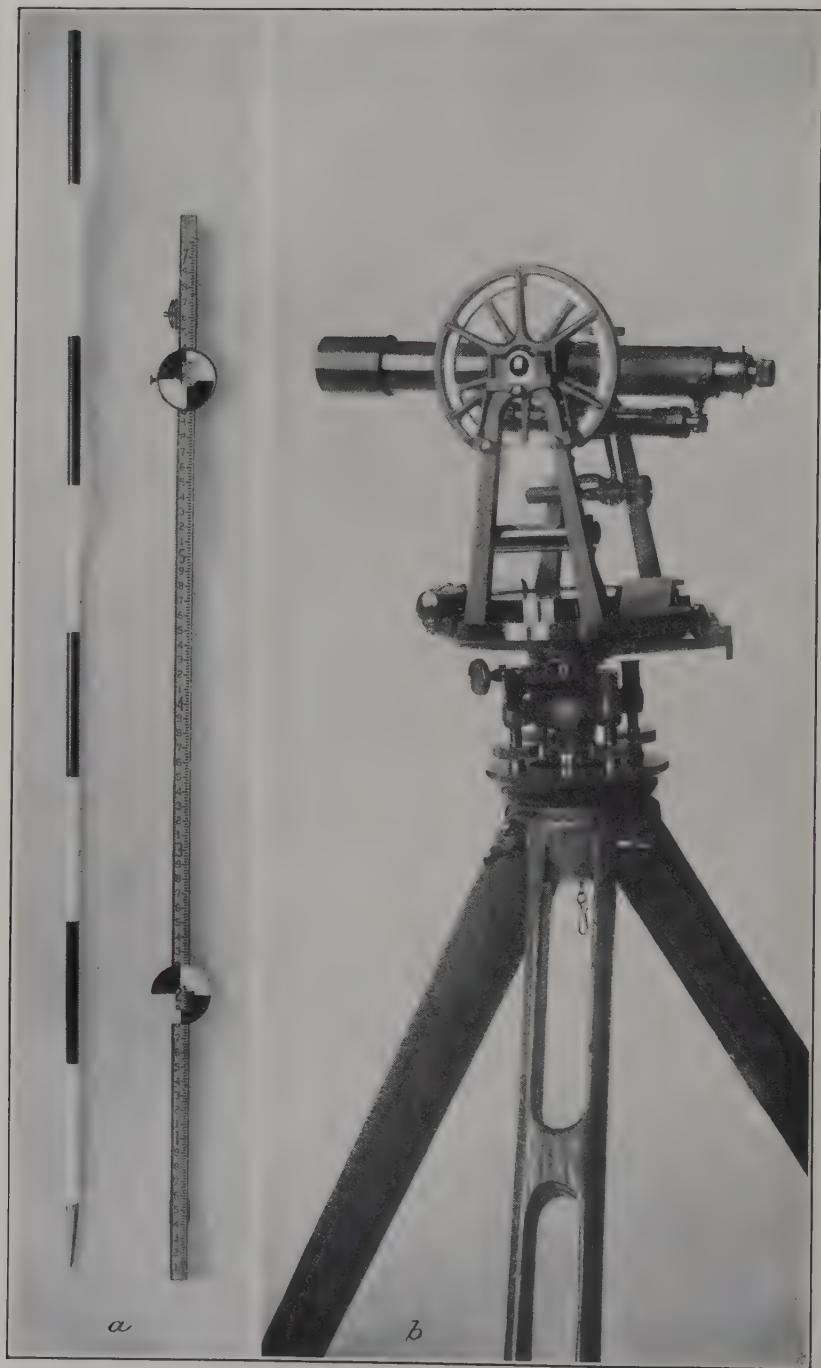
The object glasses and eyepieces of all instruments must be properly focused. The cross wires projected against a distant object should appear immovable when the eye only is moved. Before the adjustments are commenced the instruments must be firmly set up and leveled. An instrument may appear to be out of adjustment simply because some part is loose. The object glass may be partly unscrewed, or an adjusting screw may be only partly tightened; level bubbles or cross wires occasionally become loosened. Therefore, before commencing the adjustment of an instrument look out



## APPARATUS USED IN TRANSIT TRAVERSE

*a*, 300-foot tape and reel; *b*, 100-foot tape; *c*, plumb bob; *d*, spring balance; *e*, hand counter; *f*, thermometer; *g*, flash light; *h*, steel dies





VERNIER TRANSIT (b), STADIA ROD (a, right), AND RANGE ROD (a, left)

for such defects. When it is thought that an adjustment has been completed, always test it before using the instrument. All adjusting screws should be screwed tight enough to hold, yet not so tight as to injure the threads or put a severe strain on any other part. Especial care should be taken not to strain the cross-wire screws. Adjustments should be made in the order given under the following headings, for some adjustments depend on the accuracy of others previously made, and a change in any one may affect the others.

#### MINOR REPAIRS

*Setting of bubbles.*—For setting level bubbles a small supply of plaster of Paris should be kept on hand. For use the plaster should be mixed with water to the consistency of a thick paste. If plaster is lacking, strips of paper may be used, but these should never be jammed in very tight, as the pressure may distort the glass and thus vitiate the bubble reading by an appreciable amount. A reflecting surface of colored paper should be placed under the bubble in order to make the graduations more readable; a subdued green or blue tint is recommended.

*Mounting of cross wires.*—For mounting cross wires a small bottle containing shellac dissolved in alcohol, a pinch of beeswax, and a pair of dividers or a forked stick are needed. The best spider web is, of course, a freshly spun one from a small spider, for this will be both clean and elastic; but as spiders are not always available, it is well to keep on hand a spider cocoon. Such a cocoon will furnish webs enough to last for years, although with age the threads become stiff and brittle and therefore more liable to break from a jar to the instrument. Most webs taken from grass or bushes are rough, coarse, and dirty.

To draw the reticule from the instrument, unscrew and remove the eyepiece slide; then take out two opposite capstan-headed screws and loosen the other two. Using the latter two as handles, revolve the cross-wire ring  $90^\circ$ , insert a pointed stick through the end of the telescope tube into a screw hole in the ring, and, using it as a handle, remove the other capstan screws and draw out the ring. To replace it in the telescope, reverse this procedure. When in place the cross wires should be on the side of the ring toward the eyepiece.

Having pressed a bit of beeswax to each prong of the dividers or forked stick, let a small web fall from the end of one of the prongs, or pick with it from a cocoon a single thread, pressing the thread into the beeswax, stretch the thread moderately, and attach to the wax on the other prong. If an old web is used, it should first be dampened by dipping in water for a few seconds. In place of the dividers

or forked stick, small sticks or lumps of wax may be attached to the web about 2 inches apart. Place the web across the reticule, using a magnifier to insure its coinciding exactly with the marked lines. Put a small drop of shellac on each end and leave until dry.

Instruments such as the prism level, dumpy level, and transit, which are not provided with Ys or similar devices for adjusting the cross wires, may be put in close adjustment by means of improvised wooden or metal Ys.

#### ADJUSTMENT OF TRANSIT

*Plate levels.*—With lower plate clamped and upper plate loose, level carefully; revolve the instrument  $180^\circ$  on its vertical axis and bring each level bubble halfway back to the center of the tube by means of the screw at one end.

*Collimation.*—Level carefully, sight on a point about 500 feet distant, raise or lower the telescope slightly, and note whether the vertical wire remains on the point; if not, loosen the capstan-headed screw and turn the cross-wire ring till the vertical wire will remain on the point when the telescope is raised or lowered. Clamp the instrument, set the vertical wire so that it cuts the point selected, transit the telescope by revolving it  $180^\circ$  on its horizontal axis, and select a second point 500 feet distant in the opposite direction from the first. Unclamp the upper plate, turn the transit  $180^\circ$  on the vertical axis, releve if necessary, set it on the point first selected, and again clamp the plate. Transit the telescope, and if the vertical cross wire exactly bisects the second point its adjustment is perfect; if it does not, bring it one-quarter of the way back to the second point by turning the two capstan-headed screws on the sides of the telescope.

*Standards.*—Set up the transit near a tall building or other high object; after leveling carefully, point the telescope so that the vertical wire intersects a definite point about  $60^\circ$  above the horizontal, depress the telescope, and select a second point near the ground. Unclamp the upper plate, revolve the telescope and plate  $180^\circ$  on the vertical axis, clamp the plate with the vertical wire again cutting the upper point, and depress the telescope; if the cross wire intersects the lower point, the standards are in adjustment; if it does not, correct for one-half the error by the screw underneath one end of the telescope axis.

*Object-glass slide.*—If an adjustment for the telescope object-glass slide is possible, it is made as follows: First make the collimation adjustment for a point about 300 feet distant, then focus on a point 1,000 feet or more distant and again on a point only 10 or 15 feet distant, transit the telescope, unclamp the plate, turn it  $180^\circ$  on the

vertical axis, and reclamp. If the cross wire still cuts the distant and near points, the slide is in perfect adjustment; if it does not, correct half the error by means of the side screws that hold the slide ring in place. Next repeat the regular collimation adjustment and again test for the slide error; repeat both adjustments until no errors appear.

*Eye-piece tube.*—The eyepiece may be put into position over the cross wires by turning the screws that hold the eyepiece ring until the cross wires appear in the center of the field; an exact centering is not required.

*Telescope level.*—If there is a level attached to the telescope, it may be adjusted by the "peg method" after all the other adjustments are made, as follows: Level the transit and bring the bubble to the center of the tube under the telescope. Take a reading on a leveling rod or pole 300 or 400 feet distant, which is held on a stake set firmly in the ground. Revolve the transit  $180^\circ$  on the vertical axis and after again bringing the bubble to the center set a second stake at the same distance as the first and at such an elevation that the rod or pole reading is the same as on the first stake. The tops of the two stakes will then be at the same elevation. Move the transit 25 or 50 feet back of one stake and on a line with the other. Make the telescope as nearly horizontal as possible by means of the attached level, clamp it, and then take a reading on the rod held on the near stake and another reading on the distant stake. If the two readings agree, the telescope is horizontal; if they do not agree, turn the tangent screw so as to bring the cross wire while set on the distant rod nearly to an agreement; repeat the operation until an agreement is reached. The telescope is then level, and the adjusting nuts at the end of the level tube should be turned until the bubble is brought to the center.

*Vertical circle or arc.*—The screws holding the vernier for the vertical arc should now be loosened and the vernier moved until the reading is  $0^\circ$  while the telescope is still level.

#### GENERAL REQUIREMENTS

*Location of line.*—Transit traverses should always be run in circuits or tied to points previously located. In a 15-minute quadrangle, in country where routes can be readily planned, traverse lines should follow as closely as possible the borders of the quadrangle to be controlled, not departing from them more than is necessary to keep on roads. If there is a choice of roads, select the one in an unmapped area. An additional east-west line should be run to bisect the quadrangle. In areas where the country will not permit this plan to be followed economically and where the selection of routes



for the lines must be influenced by the location of highways, it will be necessary to plan the routes to meet the specific requirements.

*Permanent marks.*—In areas where topographic conditions permit a tablet (see pl. 4) in a concrete post must be placed as near as possible to each corner of each 15-minute quadrangle, one on each side halfway between the corners, one in the center of the quadrangle, and others at average intervals of 3 miles along other parts of the lines. All such marks must be stations on the lines and unless they have already been marked by a levelman should be stamped "Trav. Sta. No. —" (numbered consecutively) and also with the year of survey and the initial letter of the traverseman's surname. In areas that can not be traversed according to the regular plan permanent marks must be established at intervals not greater than 3 miles.

In cooperating States the appropriate tablet (A, pl. 4) must be used.

Where level bench marks have already been established along the route of survey, they should be tied to and stamped as above and thus made to serve as permanent marks on the traverse line.

It is desirable that every permanent point be tied to two or more witness or reference points, and the true azimuths, a sketch, and the approximate or exact distance to each, with description, should be duly recorded in the notebook.

*Sites for marks.*—The sites for permanent marks should be selected with great care and be at points where they may be used by levelmen as bench marks. It should be borne in mind that the value of the work depends largely on the permanence and the accuracy of the marks. Marks that are intended to be permanent must not be placed nearer than 15 feet to a wagon road or a railroad. They should not be placed on bridges, though these may be good places for temporary marks. A concrete post may be placed on the right of way line of a railroad or highway. The right of way line at the intersection of two roads is commonly an excellent site. The marks should not be placed near old buildings that may soon be torn down, enlarged, or rebuilt. The site selected should be a place where the mark will not be in the way of anyone and will probably not be disturbed for many years. Marks set in earth in exposed localities should be surrounded by mounds of earth or stone.

*Concrete posts.*—Where solid rock or large boulders are not available, the most durable objects in which to place tablets are concrete posts. These posts may be made by contract, or if made in place, proceed as follows: Provide two or three heavy reinforcing wires of nearly the length of the proposed post, with ends bent over an inch or two; also a piece of conical sheet-iron pipe 12 inches long, 6 inches in diameter at one end and 8 inches at the other. Dig a hole

12 inches in diameter and 24 to 36 inches deep. The deepest holes are required in cold regions; a 24-inch hole is deep enough in regions where the ground seldom freezes. Place the reinforcing wires in the hole, and fill within 6 inches of the surface of the ground with concrete consisting of one part cement, two parts sand, and three parts broken stone or gravel, well mixed and moderately wet; tamp well. Set the iron pipe, large end down, over the center of the concrete block so as to inclose the wires, and space them an inch or so from the outside. Fill the pipe with cement mortar, consisting of one part cement and two parts clean sand; tamp well. In the top of the post place a tablet flush with the rounded surface of the cement. Any marks to be added to the tablet should be stamped on it before it is placed in the wet mortar. The finished post should not project more than 6 inches above the original ground surface. The post when completed should be sheltered from the sun for several days. If a mark must be established in soft or wet ground proceed as follows: Drive a wooden stake 3 by 3 inches, or larger, as far in the ground as it will go without splitting. Saw off the top about 6 inches above the ground. Place a length of glazed drain tile 6 inches or more in diameter around the stake, with its flange end at least 12 inches below the surface of the water or ground. Fill the tile with cement mortar, round off the top slightly, and set a bench-mark tablet in the top flush with the surface of the cement.

*Azimuth marks.*—Whenever practicable two or more reference marks should be established for each permanent mark, from which azimuths can be found for future use. These may be church steeples, cupolas on schoolhouses, water tanks, corners of large buildings, or any other prominent objects. If no well-defined objects are visible, copper nails in large trees 50 to 100 feet distant will serve the purpose. The distances and the angles to near-by marks should be measured. A sketch helps the computer avoid errors in finished work. All reference marks and the azimuths to them must be described and reported, together with the computed results of the line.

*Additional points.*—Besides the permanently marked points, a number of other points should be carefully located along the traverse, and these points should be specifically designated in the field notes. Of special importance are the crossings of boundaries of States, counties, and civil townships, and the locations of the principal crossroads, railroad and highway crossings, railroad stations, and township and section corners. Note should also be made of less important landmarks, such as road forks, mileposts, railroad switches, and stream crossings. These points should be so completely described in the notebook as to be readily identified.

*Control for airplane photographs.*—In view of the extensive use of airplane photography for mapping, all points on a traverse line that can be easily identified from the air must be located.

Maps are most successfully compiled from aerial photographs when the control traverses are run after the photographs have been made. By this arrangement routes for traverses that will most effectively control the photographs may be selected. It is absolutely essential that traverse points be located near each end and the center of an area covered by a tri-lens photograph in order to control it properly, and the chance of getting such a combination of points is very much reduced if the arrangement of the areas to be photographed in the quadrangle is not first considered. This condition does not apply to single-lens photographs, for which the ordinary rules for the distribution of traverse lines may be followed.

Control points for aerial photographs should be selected with due regard to easy identification, and only such points as are clearly shown in the photographs should be chosen for computation. Gates, trees, wire fences, windmills, houses, and indefinite road intersections are unsuitable. Road forks, road intersections, well-defined angles in roads or streams, stream crossings that intersect roads at right angles, fence lines defined by a growth of trees or brush, sharp angles in woodland boundaries, and railroad crossings usually make good points for identification.

*Level bench marks.*—The work must if possible be so arranged that the levelman can determine an elevation for each traverse mark; therefore the party that precedes should endeavor to select sites for marks suitable for the other party, and the descriptions made by both parties should agree. Copies of the descriptions should be forwarded daily to the party following.

*Land survey corners.*—Diligent search and inquiry should be made for marks on the public-land surveys, and accurate connections should be made with each one that is found. It is very important that numerous corners be located for the topographer. In areas where unusual difficulty is experienced in finding corners the General Land Office will, on request through the Washington office, detail a cadastral engineer to assist in the search.

*Accuracy.*—For all circuit closures in new work or ties between located points of the same or a higher order an accuracy of not less than 1 in 5,000 (about 1 foot to the mile) must be maintained.

For main or trunk control traverses that follow routes near the borders of each full degree quadrangle an accuracy of 1 in 7,500 must be maintained—that is, the initial and computed positions of a tie point must not show a difference of more than 1 part in 7,500 of the length of the traverse line. To insure such a degree of accuracy especial care must be taken in making the measurements of dis-



tance. The front tapeman should be a man of experience and should be held responsible for proper procedure.

*Highway surveys.*—Highway surveys may often be substituted for or used as transit-traverse lines. The field notes for these surveys can usually be obtained from the office of the State highway department, which is generally at the State capitol.

The methods of surveying highways are similar to those used in transit traverse, except that the true azimuths of the lines are seldom given; but approximate azimuths may be based on a magnetic bearing of the first course, to which has been applied the deflection angle at each transit station. If no true azimuths are known, it will be necessary to tie to at least two adjacent stations near the beginning of each highway survey and to observe for the true azimuth of that course. Additional azimuths should be determined at stations not more than 10 miles apart.

Field notes of highway surveys should be copied in book 9-928. In these notes each station is usually referred to two or three points; the descriptions of these points should be copied from the field notes and used in tying to the stations at which azimuth observations are to be made.

The results of each azimuth observation should be computed in the field as soon as the observation is made, and the bearings from the highway surveys should be checked between observations.

In copying field notes of highway surveys all road forks, bridges, railroad crossings, civil boundary lines, and junctions with other highway surveys should be noted for computation.

Highway surveys must always be tied to triangulation or transit-traverse stations by running a traverse line from a station on the highway survey to a station of higher order.

#### FIELD METHODS

*Duties of tape men.*—The front tape man must carefully mark off each tape length, if on a wagon road, with tally pins; if on a railroad tangent, with keel on the rail. Each time he marks off a tape length he registers it on his hand recorder; each time the rear tape man reaches the mark left by the front tape man he does likewise. When a transit station is established the two tape men compare their hand records for check on the measurement. Should they differ, the course must be remeasured.

Transit stations should be made at even tape lengths or even 10-foot marks, wherever possible, in order to simplify the work of the computer. They should be selected at points affording not only an unobstructed view back to the transit but also a clear view forward. Each station is to be marked, if on a wagon road, by a 10-penny



nail driven into the ground through a piece of paper on which the front tape man has written the number of the station and the distances; if on a railroad, by a keel cross on the rail with the number and distance on the nearest tie.

Stations on main lines are to be numbered consecutively, beginning with zero; those on short spur lines to section corners or other points to be computed are to be lettered instead of numbered. Station numbers should never be duplicated in a single locality.

The two tape men must keep in book 9-929 separate records of the number of stations and distances between them. At noon and at night these records must be compared with the recorder's notes, and should there be a difference it must be corrected before the line is carried forward, the line being retraversed if necessary.

In locating transit stations the front tape man should bear in mind that it is desirable for the instrument man to be able to sight the bottom of the rod in each direction. This is especially important on short sights, for errors due to sighting the upper part of a rod which may be out of plumb may appreciably affect the accuracy of the line.

*Method of measuring.*—When measuring along a wagon road the tape must be kept horizontal unless the grade is very slight; on short steep slopes a plumb bob must be used either to bring the tape end vertically over an established point or to establish a new point. Judgment should be used in selecting the proper length of tape on short slopes; no attempt should be made to use the full 300-foot length; about 150 feet is ordinarily all that a tape man can hold horizontal with the proper tension and plumb at the same time. On slopes that require "breaking" the tape into short sections, the entire tape should first be drawn forward its full length by the front rodman if convenient, or by the front tape man, who then returns to help "break" the tape at the proper places, until the end of the tape is reached. In this manner the distance is measured on the whole tape and does not depend on the sum of the separate horizontal measurements.

On long regular slopes the distance on the slope should be measured and recorded and the angle of slope measured with the transit. The corrections for slopes of  $1^{\circ}$  or  $2^{\circ}$  for short distances are negligible.

*Test of tape.*—A tested tape will be supplied to each party and should be kept in reserve; the tape used in measuring should be compared with the tested tape each week and the results made a part of the record. A tape when in use should always be stretched by means of a spring balance to a tension of 20 pounds.

*Tape errors.*—Tests of tapes by the Bureau of Standards seldom disclose errors as great as 0.01 foot in 300, but occasionally for a patched tape the error runs as high as 0.06 foot. Great care should be taken when a broken tape is patched to see that the length of the section is not changed. Before any tape is used in the field the length should be checked up by the chief of party, by comparison with an unbroken standardized tape.

A difference of  $7\frac{3}{4}$  feet in the elevation of the ends of a 300-foot tape will shorten the horizontal distance 0.1 foot. A difference in elevation of  $2\frac{1}{2}$  feet will shorten the distance 0.01 foot.

Geological Survey 300-foot steel tapes are standardized at a temperature of 68° F. and a tension of 20 pounds. A variation of 10° above or below this temperature will change the length of the tape 0.02 foot. Differences of temperature of 20° or 30° above or below 68° are common and for such differences corrections should be made in the recorded figures for distance, which should be increased for temperatures above 68° and decreased for temperatures below 68°.

A change in tension of a Geological Survey 300-foot steel tape from 20 to 25 pounds increases its length 0.016 foot. A decrease in tension from 20 to 5 pounds shortens the tape 0.047 foot.

The correction for sag (always negative) for a 300-foot tape supported at 50 foot intervals under a tension of 20 pounds is 0.016 foot.

*Errors in taping.*—The errors that most seriously affect the accuracy of taped lines may be grouped in two classes.

The errors of one class are due to failure to keep the tape horizontal and to careless plumbing. The instrument man should impress the tape man with the fact that the accuracy of traverse depends on the taping more than on the instrumental work, for the latter is checked at every azimuth observation, whereas there is no check on the taping until the circuit is closed.

The errors of the other class are gross mistakes, arising generally from carelessness in counting tape lengths. They may be eliminated by checking the count of tape lengths by independent measurements. To do this, the instrument man should measure each distance by stadia, using the red and white transit rod or a special stadia rod carried for this purpose. In case the distance is too great to be read by a single sight, he should set up the transit between stations and read both front and rear rods. Stations should under no circumstances be more than 2,600 feet apart, which is about the limit of visibility of the rod. On a railroad an additional check on the taping may be had by counting rail lengths, but it should be remembered that rails may be 26, 28, 30, or 33 feet long. The counting should be done by both rodmen and the recorder, or by the instru-

ment man while moving from one station to the next. In other places a check may be had by pacing. The distance to a plus point should be checked, as well as the distance to the next station.

*Temperature record.*—The transit man should carry a thermometer and record the temperature every hour.

*Stadia control.*—Under certain conditions it is allowable to substitute stadia distances for tape-line measures in transit traverses for "fourth order" control of maps. Such lines should not exceed 20 miles in length and should be well checked, either by tying to a previously determined point or by closing on an azimuth station. Points on stadia lines should not be used as initial points for the extension of transit traverses.

For work of this class a Philadelphia rod with two targets should be used, one target to be fixed at the 2-foot mark, the other target to be set from signals by the transit man.

The value of the stadia interval must be accurately determined for each transit by the following method: With a steel tape measure a base line on nearly level ground and mark stations at intervals of 100, 200, 300, 500, 700, and 900 feet from the center of the transit. With the transit at station 0 read and record the rod interval at least five times for each station, setting the upper target carefully for each reading and recording intercepts to three places of decimals. Repeat the observation at intervals of two hours from 8 a. m. to 4 p. m. The means of the differences between the steel-tape distances and those found by stadia will be the corrections to apply to stadia readings before recording them. Only the corrected stadia distances are to be recorded.

Stadia stations should not be more than 900 feet apart.

#### OBSERVING AND RECORDING

*Deflection angles.*—At each station, in reading deflection angles, the instrument man should proceed as follows: Sight rear rod with transit circle set at last reading at previous station, transit telescope, sight front rod, and read both verniers. Turn instrument with the two plates clamped, the vernier remaining undisturbed; sight rear rod again and remeasure the angle. If the two results thus obtained differ more than 60 seconds, repeat the operation. Opposite vernier readings will not always give the same minutes and seconds; both must be read and recorded to the nearest second.

When the transit is carried from one station to the next, keep the upper plate clamped so as to retain the last vernier reading; after setting up the instrument verify the reading and record it as the first back-sight reading at the new station, but both verniers must be read twice at each station. By following this plan a useful check



on the readings is procured without trouble, and it also permits easy and quick computation of an azimuth at any station. The approximate azimuth of a line must be known at a station where daylight observations are to be made on Polaris, in order to determine the proper pointing for the star.

*Computing azimuth.*—If the foregoing rule has been adhered to, the azimuth of a line at any station at which the deflection angle is read twice only may be found as follows:

Find the difference between the A vernier reading for the last foresight along a preceding course the azimuth for which is known and the A vernier reading for the last foresight along any following course the azimuth of which is desired; subtract the smaller reading from the larger and divide the difference by 2. Adding the quotient to the known azimuth when the later A vernier reading is greater or subtracting it from the known azimuth when the later A vernier reading is less will give the azimuth desired.

Example:

At station 10 the last A vernier reading of foresight from station 10 to 11 is  $120^{\circ} 42' 00''$ .

At station 72 the last A vernier reading of foresight from station 72 to 73 is  $94^{\circ} 20' 00''$ .

The azimuth of line 10 to 11 is  $167^{\circ} 25' 00''$ .

$120^{\circ} 42' 00'' - 94^{\circ} 20' 00'' = 26^{\circ} 22' 00''$ .

$\frac{1}{2}$  of  $26^{\circ} 22' 00'' = 13^{\circ} 11' 00''$ .

Known azimuth 10 to 11	=	167°	25'	00''
	-	13	11	00
		<hr/>		

Azimuth of line station 72 to 73 = 154    14    00

The half angle is subtracted in this example because the second vernier reading is less than the first.

*Tangents.*—At a railroad or highway crossing where there is a long tangent the distance to the farther end of the tangent should be assumed or estimated and the deflection angle to it recorded. In the computed results the record should be made according to the following model: "Position of a point 3 miles distant, on line with R. & N. Railway tangent, latitude  $47^{\circ} 10' 20''$ , longitude  $110^{\circ} 14' 07''$ ." This record will afford data by which the topographer can accurately plot the tangent.

*Azimuth observations.*—Observations on Polaris or the sun for azimuth must be made each day if the weather permits. On a crooked line with many short courses azimuth observations should be made at points not more than 100 stations apart; on a traverse with long tangents they should fall not more than 10 miles apart. When practicable an azimuth station should be placed at each decided change in the direction of the line and where an abrupt change occurs between long and short sights. These requirements



may necessitate going back over the line in order to make the essential observations. If conditions are favorable it is possible to make azimuth observations on Polaris in broad daylight.

Both the transit and the azimuth mark must be at stations in the traverse preferably not less than 500 nor more than 1,500 feet apart. Each point should be marked by a stake with a tack or, if on a railroad, by a nail in a tie. The azimuth mark for night observations may consist of a vertical slit one-eighth inch wide and 6 inches long cut in the side of a box or tin can containing a candle or lantern, the slit to be carefully centered over the tack in the stake, or of a nail on the marked point illuminated by a lantern or flashlight shaded from direct observation from the transit.

In pointing the telescope for night observations use the electric hand lamp to illuminate the cross wires, holding it nearly in front of the object glass, or allow it to shine on a piece of paper fastened with a rubber band in front of the object glass and having in it a half-inch hole.

In clear weather Polaris can be seen with a good transit telescope several hours before sunset, but it is necessary to know the star's altitude within about 10 minutes of arc and its bearing within about  $1^\circ$  in order to get the star into the field of the telescope when it is not visible to the naked eye. The finding of Polaris in daylight may be facilitated by preparing a table of positions of the star for a month in advance. The table should give the hour angle for a selected hour of local time, also the altitude and azimuth of the star for the same time. Corrections easily applied may be found for other hour angles and for changes in latitude or longitude.

To find the altitude and azimuth with sufficient accuracy for this purpose proceed as follows:

Assume that an observation is to be made at 3<sup>h</sup> 25<sup>m</sup> p. m., ninetieth meridian (central) standard time, January 10, 1925, at a place whose latitude is  $40^\circ 10'$  and longitude  $85^\circ$  west from Greenwich, as scaled from a good map. As  $85^\circ$  is  $5^\circ$  east of the ninetieth meridian the watch is five-fifteenths hour, or 20 minutes, slower than local time. The observation is therefore to be made at 3<sup>h</sup> 45<sup>m</sup> local mean time.

The ephemeris (p. 1) shows that the nearest upper culmination of Polaris, which is then on the meridian above the pole, occurs at 6<sup>h</sup> 15.6<sup>m</sup> p. m. January 10, 1925, Greenwich mean time. The correction to reduce this culmination time to  $85^\circ$  west longitude time is  $-0.9^m$ .

Local time of upper culmination	= 6 <sup>h</sup> 15.6 <sup>m</sup> - 0.9 <sup>m</sup> -----	6 <sup>h</sup> 14.7 <sup>m</sup>
Assumed observation time	-----	3 45
Hour angle of Polaris	-----	2 29.7

Always take the nearest upper-culmination time, whether it is before or after the observation time.

From the table on page 22 of United States Geological Survey Bulletin 650 the bearing of Polaris for latitude  $40^{\circ} 10'$  and an hour angle of  $2^h 29.7^m$  (before upper culmination) was found to be  $0^{\circ} 53' 07''$ . Polaris was therefore about  $53'$  east of true north at the time and place of observation. This is not the exact bearing, but it is near enough for the purpose. When this table is not at hand the bearing can be computed from the table on page 10 of the ephemeris.

The altitude of Polaris may be found from the tables on page 26 of Bulletin 650. It may also be found by reversing the operation called for by the tables on page 12 of the General Land Office ephemeris or by means of the following formula:

$$\text{Sine of altitude} = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t$$

where  $\phi$  = the latitude of the place,  $\delta$  the declination of the star, and  $t$  its hour angle east or west of upper culmination.

With the transit in good adjustment set off on the vertical arc an angle of  $41^{\circ} 03'$  (the altitude); next focus the telescope very carefully for a distant pointing. It is well to focus the telescope on a star at night and then mark the focusing slide so that it can be set at the same place at any time, for unless the telescope is properly focused the star can not be found in the daytime.

If an approximate true north bearing is not known, obtain it by compass, making proper allowance for declination. Point the telescope  $0^{\circ} 53'$  east of true north, as found by computation or by the needle. If the air is clear and the star can not be seen in the field of the telescope, turn the transit on its vertical axis slowly, without disturbing the vertical-circle setting, for a degree or two to the right or left to correct any imperfect pointing in azimuth. When the star is seen turn the tangent screws of both the vertical and the horizontal axis so that the cross-wire intersection will cover it, and then proceed with the observation for azimuth in the manner described below, which is applicable to observations at any hour of the day or night when the star is visible.

Angles may be read as follows: Set on azimuth mark, then on star; reverse telescope; set on star, then on azimuth mark. Each set of observations should consist of not less than three direct and three reverse measurements, the circle being shifted for each set by about  $60^{\circ}$ . Observations may be made at any time the star is visible but preferably when it is at or near elongation. The time of setting the cross wires on the star should be recorded to the nearest second. Observations should be made rapidly; not more than 15 minutes need be taken to complete a set. The notes should be kept in the form which follows:

Date: January 10, 1925.

Azimuth observation at station 332, mark at station 333.

Latitude  $40^{\circ} 10'$ , longitude  $85^{\circ}$  west of Greenwich.

Watch 35 seconds fast of ninetieth meridian standard time (not daylight-saving time).

	Vernier A			Vernier B			Mean			Angle mark to star			Watch time		
	°	'	"	°	'	"	°	'	"	°	'	"	H.	m.	s.
Mark.....	279	06	30	99	06	00	99	06	15						
Star.....	333	02	30	153	03	00	153	02	45	53	56	30	3	40	18
Star.....	153	01	30	333	01	00	153	01	15	53	56	45	3	41	20
Mark.....	99	06	00	279	05	00	99	05	30						
Mark.....	172	02	00	352	02	30	172	02	15						
Star.....	225	56	00	45	56	00	225	56	00	53	53	45	3	45	00
Star.....	45	55	00	225	54	30	225	54	45	53	52	30	3	46	45
Mark.....	352	02	30	172	02	00	172	02	15						
Mark.....	40	56	00	220	56	00	40	56	00						
Star.....	94	46	30	274	46	30	94	46	30	53	50	30	3	50	19
Star.....	274	46	00	94	45	30	94	45	45	53	49	30	3	52	36
Mark.....	220	56	00	40	56	30	40	56	15						
Mean.....										53	53	05	3	46	03
Watch fast.....															35
													3	45	28
													3	45	5

Because of the difficulty of finding Polaris for daylight observations it is often advantageous to record the reading on the star first, then on the mark, and last on the star.

For daylight observations when the star is only dimly seen it is not advisable to shift the horizontal circle between readings, as to do so would make it more difficult to find the star again.

On the same page with the other records the latitude and longitude of each azimuth station, scaled to the nearest minute from the best map available, should be recorded, together with the date of observation, the watch error, and a statement as to the time zone used and whether or not the watch was set for daylight-saving time.

An example of computation for either daylight or night observations on Polaris is here given:

January 10, 1925, ninetieth meridian time. Latitude  $40^{\circ} 10'$ , longitude  $85^{\circ} 00'$ .

Instrument on station 332; mark on station 333.

January 10, 1925, ninetieth meridian standard time of observation	H.	m.	s.
(correction having been made for watch error).....	3	45	28
Correction for $5^{\circ}$ east of longitude $90^{\circ}$ .....	+	20	00
Local mean time of observation.....	4	05	28
	(4	05.5)	

The nearest upper culmination of Polaris as given in tables is  $6^h 15.6^m$  p. m., January 10, 1925, Greenwich mean time, civil date. The correction (always negative) to reduce to local meridian is  $\frac{8.5}{360}$  of daily change ( $3.9^m$ ) =  $0.9^m$ .

Local mean time of upper culmination, January 10, 1925, p. m.	H.	m.
( $6^h 15.4^m - 0.9^m$ ).....	6	14.7

	H.	m.
Hour angle, being the interval between time of observation ( $4^h 05.5^m$ ) and time of culmination_____	2	09.2
With this hour angle as an argument and the declination for the given date ( $88^\circ 54' 25''$ ), find by double interpolation from the table of azimuths of Polaris of the Land Office tables (p. 10) the azimuth angle for the latitude and time_____		$0^\circ 46.9'$
As the star has not reached culmination it is east of north ( $180^\circ$ ) or, $180^\circ$ being added, has an azimuth of_____	180°	46.9'
Subtract from this angle the measured angle between mark and star _____	53	53.1

The star being east of the mark, the remainder is the true azimuth of the mark on station 333 from station 332\_\_\_\_\_ 126 53.8

A rough check of this azimuth may be obtained by comparing it with the observed magnetic bearing, allowance being made for declination.

*Sun observations.*—When it is impracticable to take observations on Polaris for azimuth, observations on the sun may be taken instead, but such observations should not be taken within two hours before or after noon, or when the vertical angle of the sun is less than  $15^\circ$ .

Set up the transit at a station in the line of survey, adjust and carefully level it, read the verniers and record the readings for first pointing on the rod. Point the telescope to the sun and allow the image to fall on a piece of white paper held 3 or 4 inches from the eyepiece. Focus the cross wires on this image. By means of the two tangent screws move the telescope till the vertical and horizontal wires bisect the sun's image, taking care to use the middle horizontal wire and not the upper or lower stadia wire. Read and record the horizontal and vertical angles. Repeat the pointing and reading at least five times, and after the last pointing read again on the rod. Should the reading on the rod not agree within 1 minute of the first reading, discard the entire set and make new observations.

Reverse the telescope and repeat the readings at least five times as before. This time should be recorded to the nearest minute at the first and last pointing, and the mean time should be computed.

An example of field notes for afternoon observations is given on the next page.



Instrument, station 624; rod, station 625.

Latitude 38° 53' 46'' (as scaled from any good map).

Date, November 10, 1925. Ninetieth meridian time (standard time).

	Vernier readings			Vertical angles to sun			
Rod.	0° 00' 00''	180° 00' 00''					
Sun.	90 36 00	270 36 00	17° 01'	Time of first pointing at sun 3 <sup>h</sup> 16 <sup>m</sup> p.m.			
Sun.	90 45 30	270 45 30	16 54				
Sun.	90 55 00	270 55 00	16 46				
Sun.	91 02 00	271 02 00	16 40				
Sun.	91 09 00	271 09 00	16 35				
Rod.	00 00 00	180 00 00					

Reverse telescope (relevel if necessary).

Rod.	0°	00'	00''	180°	00'	00''			
Sun.	91	30	30	271	30	30	16°	15'	
Sun.	91	38	00	271	38	00	16	10	
Sun.	91	45	00	271	45	00	16	04	
Sun.	91	54	00	271	54	00	15	59	
Sun.	92	00	30	272	00	30	15	52	Time of last pointing at sun 3 20 p.m.
Rod.	00	00	00	180	00	00			

6 36

913 15 30                      164 16    Mean time of observation 3<sup>h</sup> 18<sup>m</sup>

Mean angle, rod to sun, +91° 19' 33''.

Mean of vertical angles..... 16° 25' 36''

Correction for refraction (always minus)..... 03 14

Correct altitude of sun..... 16 22 22

Refraction tables are given in Bulletin 650, page 334, but if no tables are available the approximate value of the refraction in seconds may be taken as 58 times the natural cotangent of the sun's observed altitude.

To compute the azimuth from the field notes use the formula

$$\text{Cot}^2 \frac{\text{azimuth angle}}{2} = \frac{\sin \text{of } (S - \text{latitude}) \times \sin (S - \text{altitude corrected for refraction})}{\cos S \times \cos (S - \text{polar distance})}$$

in which  $S = \frac{1}{2}$  (latitude + altitude + polar distance).

It is necessary to obtain from tables, for the hour, day, and year, the declination of the sun—that is, the angular distance of the sun north or south of the Equator. The declination at Greenwich noon, for each day in the year, is given in a publication of the General Land Office entitled “Ephemeris of the sun and Polaris.” This ephemeris is issued about December 1 of each year for the following year.

The polar distance is the angular distance between the sun and the north pole. In winter, when the sun is south of the Equator, the polar distance is 90° plus the declination; in summer, when the sun is north of the Equator, it is 90° minus the declination. Twice a year, September 23 and March 21, it is 90°, the declination being 0 when the sun crosses the line.

The procedure to find the declination of the sun in the example given is as follows:

Observations for November 10, 1925, 3<sup>h</sup> 18<sup>m</sup> p. m., ninetieth meridian time. When it is noon at Greenwich it is 6 a. m. on the ninetieth meridian ( $90^\circ \div 15 = 6$ ; 12 noon—6 hours=6 a. m.). The mean of the times of observation is 3<sup>h</sup> 18<sup>m</sup> p. m., 9 hours and 18 minutes after 6 a. m. local time or Greenwich noon. In the tables showing the position of the sun for the year 1925 the apparent declination at Greenwich noon on November 10 is given as  $17^\circ 04' 43''$  south. The south declination is increasing at the rate of 42.37 seconds for each hour after Greenwich noon. The tables give declination for apparent (sun) time. The change from apparent to mean noon can generally be disregarded, as it will never be more than 15 seconds of arc.

The observation was made 9 hours and 18 minutes (=9.3 hours) after Greenwich noon; therefore the change in the declination of the sun since the preceding Greenwich noon was  $42.37 \times 9.3 = 394$  seconds=6 minutes and 34 seconds.

Declination (south) November 10, 1925, at Greenwich noon.....	17° 04' 43''
Correction to be added for 9.3 hours.....	6 34

Declination at 3.18 p. m.....	17 11 17
-------------------------------	----------

To find the polar distance, add the declination as above found to  $90^\circ$ :

Declination.....	17° 11' 17''
	90 00 00

North polar distance, November 10, 1925, 3 <sup>h</sup> 18 <sup>m</sup> p. m....	107 11 17
----------------------------------------------------------------------------------	-----------

To find the value of S in the formula:

Latitude.....	38° 53' 46''
Altitude of sun.....	16 22 22
Polar distance.....	107 11 17

	162 27 25
$\frac{1}{2}$ of sum.....	81 13 42=S

S.....	81° 13' 42''
Latitude.....	38 53 46

42 19 56 = S—latitude

S.....	81° 13' 42''
Altitude.....	16 22 22

64 51 20 = S—altitude of sun

S.....	81° 13' 42''
Polar distance.....	107 11 17

25 57 35 = S—polar distance

There are times when the polar distance is less than S, but always subtract the lesser quantity from the greater.

All the quantities required in the formula are now known except cot azimuth angle. To find that quantity proceed as follows:

S—latitude	42° 19' 56''	log sin	9.82829
S—altitude	64 51 20	log sin	9.95676
S—polar distance	25 57 35	colog cos	0.04619
S	81 13 42	colog cos	0.81674

Log cot<sup>2</sup>  $\frac{1}{2}$  azimuth..... 0.64798

Divide log by 2 to get square root.

Log cot  $\frac{1}{2}$  azimuth..... 0.32399

(The cologs of cosines are the log cosines subtracted from 10.)

Angle corresponding to log cot 0.32399=25° 22' 22''= $\frac{1}{2}$  azimuth.

Azimuth of the sun..... 50° 44' 44''

Angle between rod and sun..... +91 19 33

Azimuth at station 624

to station 625..... 319 25 11=S. 40° 34' 49" E.

If the angle between the rod and the sun is plus, subtract it from the azimuth of the sun; if minus, add it.

An example of field notes for morning observations is given below.

Instrument, station 426; rod, station 427.

Latitude, 42° 36' 24''.

Date, August 14, 1925. 75th meridian time.

Vernier readings		Vertical angles to sun		
Rod.	0°00'00'' 180°00'00''			
Sun.	312 40 00 132 40 00	38°55'00''	Time of first pointing at sun 8 <sup>h</sup> 40 <sup>m</sup> a.m.	
Sun.	312 50 30 132 50 30	39 04 00		
Sun.	312 58 30 132 58 30	39 11 00		
Sun.	313 07 00 133 07 00	39 17 30		
Sun.	313 14 00 133 14 00	39 22 30		
Rod.	0 00 00 180 00 00			
Reverse telescope.				
Rod.	0°00'00'' 180°00'00''			
Sun.	313 39 00 133 39 00	39°40'30''		
Sun.	313 48 30 133 48 30	39 49 30		
Sun.	313 58 00 133 58 00	39 57 00		
Sun.	314 08 30 134 08 30	40 03 00		
Sun.	314 16 00 134 16 00	40 10 00	Time of last pointing at sun 8 44 a.m.	
Rod.	00 00 00 180 00 00			
<hr/>		<hr/>		
3134 40 00		395 30 00	17 24	

Mean of readings 313° 28' 00''. Mean time of observation..... 8<sup>h</sup> 42<sup>m</sup>

Subtracting mean from 360° gives mean angle, rod to sun, 46° 32' 00'' east of south.

Mean of vertical angles..... 39° 33' 00''

Correction for refraction..... 01 10

Correct altitude of sun..... 39 31 50

The azimuth is computed from the field notes according to the formula given on page 106.

Observations for August 14, 1925, 8<sup>h</sup> 42<sup>m</sup> a. m., seventy-fifth meridian time. When it is noon at Greenwich it is 7 a. m. on the seventy-fifth meridian ( $75 \div 15 = 5$ ; 12 noon—5 hours=7 a. m.). The mean of the times of observation is 8<sup>h</sup> 42<sup>m</sup> a. m., 1 hour and 42 minutes (=1.7 hours) after 7 a. m. local time or Greenwich noon. In the tables showing the position of the sun for the year 1925 the sun's apparent declination at Greenwich noon on August 14 is given as 14° 27' 08" north. The declination is decreasing at the rate of 46.12 seconds for each hour after Greenwich noon. The observation was made 1.7 hours after Greenwich noon; therefore the change in the declination of the sun since the preceding Greenwich noon is  $46.12 \times 1.7 = 74$  seconds=1 minute and 14 seconds.

Declination (north) August 14, 1925, at Greenwich	
noon .....	14° 27' 08"
Correction to be subtracted for 1.7 hours.....	1 14
Declination at 8 <sup>h</sup> 42 <sup>m</sup> a. m.....	14 25 54

Subtracting the declination from 90° gives the polar distance:

	90° 00' 00"
Declination .....	14 25 54
Polar distance, August 14, 1925, 8 <sup>h</sup> 42 <sup>m</sup> a. m.....	75 34 06

To find the value of S:

Latitude .....	42° 36' 24"
Altitude of Sun.....	39 31 50
Polar distance.....	75 34 06
	157 42 20
½ of sum.....	78 51 10 =S
S .....	=78° 51' 10"
Latitude .....	=42 36 24
	36 14 46 =S—latitude
S .....	=78° 51' 10"
Altitude .....	=39 31 50
	39 19 20 =S—altitude
S .....	78° 51' 10"
Polar distance.....	75 34 06
	3° 17' 04"=S—polar distance

To find the azimuth angle of the sun from the data given, proceed as follows:

S—latitude.....	=36° 14' 46"	log sin .....	9.77177
S—altitude.....	=39 19 20	log sin .....	9.80187
S—polar distance	= 3 17 04	colog cos .....	0.00071
S.....	=78 51 10	colog cos .....	0.71370
Log cot <sup>2</sup> ½ azimuth.....			0.28805
Log cot ½ azimuth.....			0.14402



Angle corresponding to  $\log \cot 0.14402 = 35^\circ 40' 10'' = \frac{1}{2}$  azimuth.

Bearing of sun,  $71^\circ 20' 20''$  (east of south).

$$\begin{array}{r} 360^\circ 00' 00'' \\ -71 \quad 20 \quad 20 \\ \hline \end{array}$$

Geographic azimuth of sun..... 288 39 40

Observed angle between rod and sun +46 32 00

Azimuth at station 426 to station

$$427 \text{ ----- } 335 \quad 11 \quad 40 = S. 24^\circ 48' 20'' E.$$

Geographic azimuths are counted clockwise from the south ( $0^\circ$  or  $360^\circ$ ; west,  $90^\circ$ ; north,  $180^\circ$ ; east,  $270^\circ$ ).

In case unfavorable weather prevents the taking of azimuth observations leave adequate marks at a point selected, before proceeding with the line, and return later to make the observations.

*Watch error.*—The instrument man must carry a reliable watch and keep it in good condition. He should ascertain its error daily by comparison with telegraphic time, which is sent over Western Union lines once a day. In case he has no opportunity to make this comparison daily while running the line, he should do so as often as possible, figure the rate of error per day, and record the proper correction for each azimuth observation made. A watch error of 20 seconds or less will not appreciably affect the accuracy of the determination.

*Magnetic declination.*—A careful reading of the needle for magnetic declination should be made at frequent intervals and recorded opposite the proper station number in the notebook. Such determinations should be made at each azimuth station and at favorable points along the line where the needle is not likely to be affected by rails, electric wires, or similar disturbing elements. At azimuth stations determine the magnetic bearing of the azimuth mark at the time it is established. If the line follows a railroad, magnetic determinations should be obtained from a parallel line at a distance of 25 yards from the rails or wires.

*Field record.*—Complete notes must be kept by the recorder in book 9-928, to be written in a plain, neat hand with a No. 4 pencil. The blanks in the title-page should be filled in the first day the book is used.

The recorder must take down the vernier readings as they are called off by the transit man and compute the mean pointings and deflection angles, giving proper signs to the angles. He must keep up with the instrument man in these computations, as they enable him to note by inspection whether the instrument man has made errors in his readings and to call attention to them before the instrument is removed from the station. He should take special pains to see that the degree and minute numbers for the two verniers are consistent and are recorded in the proper columns. A single line should be drawn through erroneous records, which must never be erased.

The notes are to be kept in the following form:

Date, September 9, 1925. Line from Pikeville to Dayton, Mo.

Station No.	Distance (feet)	Vernier A	Vernier B	Mean	Deflection angle	Azimuth	Stadia	Vertical angle
326-----	{-----	o / "	o / "	o / "	o / "	o / "		
		316 51 30	136 52 30	316 52 00	41 45 15	a 123 35 00		
		275 06 30	95 07 00	275 06 45	41 45 15	b 81 49 45	Stadia 905-----	
327-----	{-----	233 21 00	53 22 00	233 21 30				
		900			-41 45 15	a 81 49 47		
		* 233 21 00	53 22 00	233 21 30			{Sta. 327-328	
327+-----	{-----	279 04 30	99 05 00	279 04 45	45 43 15	b 127 33 30	{N. 59° 30' W	
		324 48 30	144 49 30	324 49 00	45 44 15		Stadia 1,330-----	
		1,320						
327+-----	90	Stream crossing.			+45 43 45	a 127 33 34		
327+-----	430	Crossroad at Tanbark.						
328-----	{-----	* 324 48 30	144 49 30	324 49 00	17 19 30			
		342 08 00	162 09 00	342 08 30	17 19 00	b 144 52 45	Stadia 260-----	
		359 27 00	179 28 00	359 27 30				
328-----	{-----				+17 19 15	a 144 52 43		
		260						

a Written in red ink.

b Written with black pencil.

c From actual readings; not copied from the preceding record.

The record must contain also a description of the starting and ending points of the line, of each permanent mark established along the line, of each point which is to be computed for the use of the topographer, and of all crossings and other landmarks that may be of value to him. Such descriptions should be concise, yet full enough to leave no possible doubt as to the identity of the points described. Each should be supplemented by an explanatory sketch, if necessary, showing the deflection angles to the reference marks, as the true azimuths to these marks are required. The description should begin on the next line after the angle record.

#### Example of description of permanent mark:

Station 1025, bench-mark tablet stamped "Trav. Sta. No. 4, 1912," set in sandstone ledge, top of Walden Ridge, 3 miles northwest of Dayton, Mo., at junction of Dayton, Pikeville, and Morgan Springs roads, 325 feet west of residence of John Neilson. Reference marks: Cross cut in ledge 60.25 feet N. 25° 30' E.; spike in root of white-oak tree 14 inches in diameter, 75.60 feet N. 45° 15' W.

Examples of description of points to be computed and other landmarks:

Station 625+730 feet, center of crossroads at Antioch Church.

Station 720+320 feet, east abutment of bridge over Glade Creek.

Station 732, road fork at Johnson blacksmith shop.

Station 926+210 feet, center of track opposite semaphore, Lee station.

Station 936+300 feet, road crossing half a mile east of Sequatchie railroad bridge.

Each point to be computed should be marked with brackets in ink immediately upon its selection by the instrument man.

As soon as the records in a field book are completed, it should, if not needed for reference, be sent at once to the Survey office in Washington by registered mail. Tape man's books should be sent separate from other notes and on another day.

### TRUNK-LINE TRAVERSES

The foregoing instructions apply also to trunk-line traverses, for which an accuracy of 1 in 7,500 is required. The only difference in methods between the two grades of work is that much greater care will be required for each operation, in both the field and the office, for the trunk lines. Temperature corrections must be made, and computations carried to tenths of a foot.

### TRANSIT-TRAVERSE COMPUTATIONS

The steps in traverse computations are set forth below. The computations are made in books 9-928 and 9-931. The abstracts of results are placed on long sheets of paper. Each azimuth computation is to be made in the field notebook on the same page with the observations, and the results written in red ink in the azimuth column of notebook (see pp. 101, 111) on the line with the station occupied.

Computers should read carefully the "Suggestions to computers" on pages 86-87.

*Field computation of azimuth.*—Azimuth notes must be computed as soon as possible after observations are made and the results applied to the deflection angles. These computations must be made at odd times, when they will not interfere with other work. Errors of closure in azimuth should not be distributed until checked by a second computer either in the field or in the office. Allowance must always be made for convergence of meridians.

*Computation of deflection angles.*—The mean deflection angle is combined according to its sign with the azimuth from the preceding station, and the result placed in pencil opposite the deflection angle used. This process is repeated until the next computed azimuth, written in red ink, is reached.

The last azimuth in pencil will probably not agree with the observed azimuth. For any line not running due north or south there will be a discrepancy between observed and computed azimuths, due solely to convergence of meridians, which for latitude  $30^\circ$  will be 0.5 minute for each mile run east or west. For latitude  $49^\circ$  the amount will be 1 minute. For any latitude the convergence in minutes of arc will be the difference in minutes of longitude between the ends of the line multiplied by the sine of the middle latitude. For lines running east the computed azimuth should be less than the observed. For lines running west it should be greater.

*Adjustment of closing errors.*—If no large errors appear in the results, the discrepancy between computed and observed azimuths at the closing station is to be divided by the number of stations and a proportional correction applied to each penciled azimuth, the corrected figures being written in red ink. When a large closing error is found in a transit-traverse line look first for a compensating error of  $1^\circ$  or  $10^\circ$  in the azimuths or angles.

*Computation of latitudes and departures.*—Latitudes and departures are to be computed in book 9-931, as shown below:

*Line from Pikeville to Dayton, Mo.*

Station	Azimuth	Distance	Sine	Cosine	North	South	East	West
	° ' "	Feet			Feet	Feet	Feet	Feet
326 to 327.....	81 49 47	900	0.990	0.142		128		891
227+430 feet.....	127 33 34	430	.793	.610	262			341
					262			1,232
					134			
227+430 feet to 328.....	127 33 34	890	.793	.610	543			706

Natural sines and cosines for the azimuths given are written in the appropriate columns. By means of Crelle's tables the products of these quantities by distances are found and placed in the proper columns. The sines multiplied by the distance give departures east or west. When the sine is positive, the new point is west; when negative it is east. Cosines multiplied by distances give latitudes north or south. When the cosine is negative, the new point is north; when positive it is south. The direction of the new point can readily be determined by noting the azimuth, remembering that  $0^\circ$  azimuth is for a line running due south,  $90^\circ$  for a line due west,  $180^\circ$  for a line north, and  $270^\circ$  for a line east. In the example given in the above table the azimuth  $81^\circ 49' 47''$ , being between due south and due west, will be to a point southwest. Four decimal places in sines and cosines should be used when distances are greater than 1,000 feet.

When the Gurden traverse tables for distances 1 to 100 for single minutes of arc are available, the latitudes and departures may be written in the north, south, east, and west columns direct for each azimuth and distance.

Whenever a point is reached for which the latitude and longitude are desired, as at 327+430 feet in the example, leave six blank spaces for the computation. The data for the computation for such a point are found from the record on page 111 as follows: For the crossroad at Tanbark post office, which is on the line between stations 327 and 328, the azimuth is the same as to station 328. The distance by measurement is that given, 430 feet from station 327. In order to make the computations continuous, station 328 is taken as  $1,320-430=890$  feet



from the intermediate point used, the azimuth being the same for both points.

*Computation of latitude and longitude.*—The next step in this work is the computation of latitude and longitude. These should be determined for important points a mile or less apart. Assume, for illustration, that for station 326 (p. 111) the coordinates have been completed, and that 327+430 feet is the next location desired. Each of the four columns—north, south, east, and west—is summed; the difference between the sums of the north and south columns is placed in the column of the greater, and the difference between the east and west columns is placed in the column of the greater. The computations of latitude and longitude and the descriptions of the points are placed on the right-hand page of the book opposite the group of stations.

The logarithms of the geodetic constants for metric measures, called "the A, B, C factors," are on pages 219–290 of "Geographic tables and formulas."<sup>1</sup> Factors A and B are used to five decimal places only. These will be practically constant for a distance of 10 or 15 miles north and south, the value for the middle latitude being used.

For the example on page 113:

Log distance 134 (north)-----	2.12710
Log to reduce feet to meters-----	9.48402
Log B for latitude 39° 00'-----	8.51093
	<hr/>
	0.12205

The sum, 0.12205, is the logarithm of change in latitude in seconds between station 326 and 327+430 feet=1.32'' (north).

For change in longitude:

Log distance 1,232 (west)-----	3.09061
Log to reduce feet to meters-----	9.48402
Log A for latitude 39° 00' 00''-----	8.50914
Log secant of middle latitude-----	0.10950
	<hr/>
Log of change in longitude in seconds-----	1.19327
New point west-----	15.61''

These differences are to be added to the latitude and longitude of station 326.

When the Survey tables of M and P factors, prepared by D. H. Baldwin, are available the computation of changes in latitude and longitude may be materially shortened by adding log M to the log of distance north or south for change in latitude and by adding log P to the corresponding distance east and west for the change of longitude.

<sup>1</sup> U. S. Geol. Survey Bull. 650.

The foregoing computation would then be written as follows:  
For the latitude change:

Log distance 134 (north)-----	2.12710
Log M for latitude 39° 00'-----	7.99495

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Log of change in latitude in seconds----- <sup>2</sup>0.12204

For the longitude change:

Log distance 1,232 (west)-----	3.09061
Log P for middle latitude-----	8.10266

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Log of change in longitude in seconds----- 1.19327

To check the plotting of positions on topographer's field sheets the distance between successive positions must be computed. As few lines are as much as 1 mile in length and none over 2 miles, the latitude and departure can with sufficient accuracy be taken as the base and perpendicular of a plane triangle. The distance sought will then be the hypotenuse, and its square will be equal to the sum of the squares of the base and altitude. For distances less than 10,000 feet Barlow's tables should be used in finding squares or square roots. The distance should be written in red ink, inclosed in a circle, on the right-hand page of the computation book in the blank space between the entries for the two stations referred to. After the record is complete its accuracy may be tested by computing a side from the given distance (hypotenuse) and the other side.

*Adjustment of closures.*—These operations are repeated for each selected point until the traverse line closes back on itself or ties to another point previously determined. The errors of closure for a 15-minute quadrangle, if not in excess of 1 second in latitude or  $1\frac{1}{4}$  seconds in longitude, may be distributed proportionately between initial and closing points, provided the error is not greater than 1 in 5,000 parts of the distance between them for ordinary lines or 1 in 7,500 for trunk lines.

*Errors.*—Where so many operations are involved, errors are likely to creep into the computations. Therefore each step of the work should be checked as well as possible. The azimuth computation may be compared with the observed magnetic bearings, but because of the possibility of local variation little dependence can be placed on this comparison as a check. If the computed and observed azimuths for a line differ about 10 minutes, look for an error of that amount in the deflection angle or in the adding and subtracting of deflection

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<sup>2</sup> The difference in the fifth place is the result of carrying forward decimals from the sixth place in the first computation.

angles to azimuths. If the difference is larger, it is very likely that a wrong sign has been used for a deflection angle. To find the error, divide the difference by 2 and look for a deflection angle with an incorrect sign equal to the quotient. Errors of about  $180^\circ$  result if the recorder places the vernier readings in the wrong columns. By a careful inspection of the records it is sometimes possible to detect such an error. Many errors are due to incorrect multiplication by the distance, to the decimal point being in the wrong place, or to the product being written in the wrong column—in the north column when it should be in the south column, etc. The latitudes and departures, as well as the other steps in the work, should be computed by two persons working independently of each other; after each has completed each step of the work the results should be compared and differences corrected and verified.

A plat must be made by the computer on an approximate scale of 5 miles to 1 inch, on one or more pages of book 9-931, for each group of traverse notes. In the center of the plat of each circuit write the length of the circuit and the closing error.

## D. LEVELING

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Compiled by E. M. DOUGLAS

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### GENERAL FEATURES

#### RESPONSIBILITY

The following instructions are formulated to assist the levelman in obtaining accurate results. Before he undertakes any work for the Geological Survey he must familiarize himself with these instructions in every detail, for he will be held strictly accountable for any deviation from them and personally responsible for the proper execution of his work. In order to be sure that the instructions have been received and are understood, a postal-card acknowledgment is required from each levelman at the beginning of his season's field work. He must understand that elevations of bench marks are published for the use of engineers outside of the Geological Survey and are sometimes used for large engineering projects. They must be reliable, or the Geological Survey may be subject to severe criticism. The proper contouring of topographic maps depends wholly on the character and the accuracy of the vertical control. The levelman must therefore realize the vital importance of his work and must give to it from the start such care and attention as will insure its thorough accuracy.

Levelmen working in the same area with topographers should so arrange their work as to satisfy in every way possible the requests and needs of the topographers in respect to priority and sequence of the work. The topographer in charge of mapping an area should be certain that a copy of these instructions is in the hands of every levelman in the area and that the instructions are understood by the levelmen. In the technical details of execution of his work, however, the levelman is directly responsible to the Washington office.

When a levelman is sent to any area for work he will be furnished with special instructions and all necessary data pertaining to that area. In an area where his work has been preceded by transit traverse he must follow the traverse route if practicable, but in any area he must utilize all permanent traverse marks as bench marks, which must be turning points in the line, and he must tie his work to any permanent or substantial marks of other organizations that he may find along the line, making them turning points also.



### TYING NEW WORK TO OLD

Every bench mark from which new work is to be started must be checked by leveling to an adjacent established bench mark before the work proceeds. If the closure error between those two bench marks is not within the limits allowed, the section should be releveled, and if the closure is still out of limits the line must be continued until two old bench marks are found between which the closure comes within the limits. The initial elevation of the new work must be derived from one of two bench marks that agree. For the end of the line a tie to one bench mark will be sufficient, provided the closure is within the limits; otherwise the line must be run to a second or third mark.

A complete description must be given of all previously established bench marks to which new work is tied. Whether beginning or ending a new line, or touching older lines in any part of the new work, these junction bench marks must be so fully described that there can be no uncertainty as to which marks have been used. If the results of the older work have been published, give bulletin number and page. If the bench mark has been recently established give page references to the field book where it has previously been recorded or show from what source its data have been obtained. Give in parentheses the old elevation. Make a note describing the condition of the old mark and stating whether it shows signs of having been disturbed.

When a levelman finds a previously established permanent bench mark broken or in bad condition he must replace it or reset it. If a new tablet is used it should be stamped like the one replaced, except that if the elevation has been adjusted the new figure should be used, and a full report, including change in elevation, if any, should be sent promptly to the Washington office.

If the bench mark is also a transit-traverse mark and a horizontal change in its location is found necessary, the magnetic bearing must be taken and the distance from the original position accurately measured with steel tape. The descriptions of both the old and the new marks, their elevations, and a sketch showing their positions must be promptly transmitted to the Washington office. If the tablet previously set is incorrectly stamped the erroneous figures should be carefully cut out with a chisel and the correct figures stamped in their place and verified. This action, together with a description and a sketch of the bench mark, must be promptly reported.

### DISTRIBUTION OF VERTICAL CONTROL

The act of Congress providing for the sundry civil expenses of the Government for the fiscal year 1896-97 contains the following paragraph:

For topographic surveys in various portions of the United States \* \* \* *Provided*, That hereafter in such surveys west of the ninety-fifth meridian elevations above a base-level located in each area under survey shall be determined and marked on the ground by iron or stone posts or permanent bench marks, at least two such posts or bench marks to be established in each township or equivalent area, except in the forest-clad and mountainous areas, where at least one shall be established, and these shall be placed, whenever practicable, near the township corners of the public-land surveys; and in the areas east of the ninety-fifth meridian at least one such post or bench mark shall be similarly established in each area equivalent to the area of a township of the public-land survey.

The most advantageous locations of level lines for a 15-minute quadrangle are near the borders of the quadrangle and from east to west through the center, the same arrangement as is required for transit-traverse lines. If additional leveling control is needed by the topographer the lines should be run by the levelman as a good grade of fourth-order levels, but without setting any permanent bench marks. Permanent bench marks should not be established by means of any level lines of a grade less accurate than that described on page 130 as "third order."

#### PERMANENT BENCH MARKS

*Distribution.*—Permanent bench marks should be placed along level lines at intervals of approximately 3 miles, unless the levelman is otherwise instructed, and the distance between bench marks should nowhere exceed 4 miles. They should be established if practicable at township corners of the public-land surveys; near all large lakes and reservoirs; at crossings of the larger streams and divides; in the vicinity of active mines; and in every city, town, or large village traversed. In county seats and cities that have a population of 10,000 or more two permanent bench marks, some distance apart, must be established. Along public highways and railroads bench marks should be located where practicable at road junctions and crossings.

*Best locations.*—Permanent bench marks should be so located that they will not be liable to injury or disturbance, yet they should be so prominent as to be easily found. Along a railroad or highway they should be placed, if practicable, outside the right of way but close to it. If such a location is impracticable and they are located within the right of way care should be taken for their preservation in the event of future changes in road location. Bench-mark posts must not be set close to trees, telegraph poles, or fence posts, or in front of gateways. They should not be set in swampy soil.

Tablets must not be set in boulders within the right of way of any well-established highway, or in any part of a bridge structure.

*Permission of landowner.*—Before a bench mark is set on private property permission should be obtained from the owner or agent, but if this is impracticable written notification explaining the necessity for the mark should immediately be sent to him.

*Bench marks on Federal buildings.*—If the custodian of a Federal building objects to the placing of a bench-mark tablet in the building, the exhibition of the following copy of a letter from the Assistant Secretary of the Treasury should induce him to give the necessary permit.

TREASURY DEPARTMENT,  
Washington, December 22, 1920.

The honorable the SECRETARY OF THE INTERIOR.

SIR: By direction of the Secretary, the receipt is acknowledged of a letter from the First Assistant Secretary of the Interior, dated December 20, 1920, requesting that permission be granted to the officers of the United States Geological Survey of your department to place on the Federal buildings under the control of this department small inscribed metal tablets, which are to be used as bench marks in connection with the system of leveling, the custodians of the buildings to designate where the tablets are to be placed.

No objection will be interposed by this department to the placing of such tablets on the various Federal buildings as desired, and this letter or a copy thereof, upon its presentation to the custodian of a Federal building, is to be considered by him as his authority for permitting the placing of one of the tablets on the building in his custody.

(Signed) J. H. MOYLE,  
Assistant Secretary.

*Form, materials, and construction.*—The tablets that form permanent bench marks are fastened with cement in large boulders, in solid rock in place, in permanent masonry structures, or in the top of concrete posts. (See pl. 4.) The tablet should be countersunk so that its lettered surface is flush with the surface of the rock or concrete in which it is set.

Portland cement in air-tight cans is supplied from the Washington office for use in setting tablets in rock or in masonry already in place. If good clean sand is available it can be mixed with the dry cement in equal parts. The drill hole for the tablet must be well cleaned and wet. The cement and sand, or cement alone if pure sand can not be conveniently procured, should then be thoroughly mixed with water to a thick paste, which should be packed into the drill hole. The stem of the tablet should then be pushed into the hole, when the excess cement will be forced out and the cement will fill completely the space under the tablet. In order that the cement may set well, it should be kept damp and protected from the sun for at least a day, and for 12 hours it should not be allowed to freeze. Damp earth or a piece of sacking will probably be sufficient protection. If a tablet is set in a vertical wall a prop may be necessary to hold it in place until the cement sets.

Suitable concrete posts may be made by contract in a town where materials are available, or they may be made by the levelman at the place where they are needed. They should generally be long enough to extend below frost line, and may be square or round in section; their sides should taper, and the top should be at least 6 inches and the bottom about 12 inches across. The post should be reinforced by three or four pieces of heavy galvanized-iron wire. The top of the post should not project more than 6 inches above the natural surface of the ground. The concrete should consist of 1 part cement, 2 parts sand free from loam or clay, and 3 parts coarse gravel or broken stone. The upper 12 inches of the post should be made of a mixture of 2 parts sand to 1 part cement, without any gravel or stone, and the tablet should be put in position in the top of the post when the post is made. The mixture should be made up with just sufficient water to moisten it thoroughly, and it must be well tamped in the mold. An excess of water is harmful. The post, when completed, should be sheltered from the sun for several days and wetted frequently if practicable.

The point of elevation on all tablets, whether set vertically or horizontally, is the intersection of the cross lines inside of the triangle.

*Reference marks.*—A reference mark, which shall be made a turning point in the line or be on a checked spur line, must be established near every permanent bench mark. Reference marks should conform to the instructions given for supplementary bench marks and should be described with equal care.

*Establishing marks after line is run.*—If conditions make it necessary to leave the setting of a permanent bench mark till after the line is run, two temporary bench marks (both of them turning points in the line) must be left near the point selected, one of which is to be a reference mark. The elevation of the permanent bench mark must be determined by readings on both of the temporary marks from two different set-ups. A single "side shot" is never sufficient in establishing the elevation of a bench mark.

*Painted elevations.*—The letters "U. S. B. M.," together with the determined elevation to tenths of a foot, arranged when practicable thus:

U. S.  
[figures]  
B. M.

must be neatly painted in letters and figures 4 inches high on some convenient object near every permanent bench mark in order to insure its being readily found by the topographer or traverseman. When no suitable object is found on which to paint, a mound of rock or



earth large enough to attract attention must be left. The painted elevations must be in no way objectionable or offensive to the owners of property or to travelers. Prominent trees along public highways must not be defaced by blazing except as a last resort.

*Stamping.*—To facilitate the identification of permanent bench marks, an individual letter will be assigned by the chief of division to each levelman, which he must stamp on all tablets set by him. He will also stamp on each permanent bench mark a number, which will be serial for all tablets set by him in any one State during one season, and this number must be followed by figures showing the year in which the work was done. For example, "C-10-1920" means that the line was run by levelman C and that it was the tenth permanent bench mark set by him in that State in 1920. These letters and figures will be stamped beneath the space left for the figures showing the elevation and must be stamped before the bench mark is set; they should be in two lines, the figures for the year on the second line. If the mark is both a transit-traverse mark and a bench mark, the control man who first establishes the mark should stamp it with his letter and serial number. The second man should not add his own stamping to this but should use the first man's letter and number to identify the mark.

Figures of elevation must not be stamped on metal bench marks until the level lines have been adjusted and the final elevations supplied by the Washington office. Usually the elevations can not be stamped until the field season after the marks are set, and the stamping may be done by a different engineer from the one who set the marks.

Stamping must be neatly done, so that the figures are perfectly legible. Metal bench marks are to be stamped only to the nearest foot of the adjusted elevation, as indicated below:

Elevation	Stamping
1328.675	1329
1474.428	1474
1492.501	1493
1237.500	1238
1238.500	1238

If the decimal .500 follows an even number, disregard it. If it follows an odd number, add 1 to the number.

A list of marks to be stamped is furnished to the engineer. Write in ink on this list the figures of elevation as stamped, also make an impression on the margin of the list or on a separate piece of paper of the elevation stamped and the identifying letter, number, and year. An impression of all markings can be made by first smearing the surface of the tablet with printer's ink and then applying to it

and rubbing down a piece of white paper, or by holding the paper firmly on the tablet and rubbing over it with a soft lead pencil.

If a tablet is wrongly stamped, as soon as the error is discovered cut out with the small cold chisel supplied the erroneous figures and restamp the correct ones. If the erroneous figures have been reported to the Washington office the correction should also be reported.

The list should be returned to the Washington office as soon as the stamping is completed.

#### SUPPLEMENTARY BENCH MARKS

As descriptions of supplementary bench marks are published in level bulletins and their elevations are given on topographic maps, careful attention must be given to their character and location, in order that they may be made as permanent as possible and easily accessible. They should be placed where they are least likely to be disturbed and yet can readily be found from the descriptions.

Supplementary bench marks must always be turning points in the main line and should be set at intervals of half a mile to a mile on all lines. On railroads and highways they should be set at the principal crossings, crossroads, and road intersections. They may consist of well-defined chiseled marks, preferably forming a square, on solid rock in place or on permanent structures of concrete or stone, or bolt heads surrounded by painted rings on steel structures, or copper nails with lettered washers in exposed roots of suitable trees. No other form or material less substantial than those above specified should be used for supplementary bench marks.

The elevations of all supplementary bench marks as at first determined by the levelman must be painted to tenths of a foot on some convenient object near by, as explained on page 124.

#### USEFUL ELEVATIONS

The levelman should bear in mind that his work is not an end in itself but a preparation for the work of others and that the accuracy with which his circuits check, though of paramount importance, is not the only feature that determines its usefulness.

Besides the elevations of the permanent and supplementary bench marks a number of other elevations are required for the use of the topographer, and they should be distributed with a special view to their usefulness in topographic mapping. For instance, an elevation painted on a summit will be of great value to the topographer, whereas one painted below it, simply because a turning point can more easily be made there, is of far less value.

The points for which elevations are particularly useful are the tops of rails at railroad stations, junctions, sidings, and crossings;

the center of the road at crossroads, road forks, bends, and summits; points near schoolhouses and other public buildings, lone houses, active mines and quarries, and oil, gas, and artesian wells; the water surface of streams under bridges, at stream crossings, and above and below dams; and the water surface of lakes and reservoirs. The date and hour when the measurement of a water-surface elevation was made should be recorded.

The number of these elevations should differ according to the nature of the country and the contour interval used for the map. Thus, in rugged regions mapped with 50 or 100 foot contour intervals relatively few elevations are required, but in areas of gently rolling surface they should be more numerous.

Elevations should be determined to the nearest tenth of a foot for such of these points as are of a definite nature—for example, the top of a rail or a bridge floor.

Ground elevations (to the nearest foot only) should be neatly painted in conspicuous places along the sides of roads and on fences, telephone poles, trees, or rocks. If practicable, all such marks along a road should be placed on the same side of the road. On a bridge the elevation of the floor should be painted on the railing or truss immediately above it, not on the floor itself.

#### NOTES AND RECORDS

The fly leaf of every field book should be filled in before any other records are put in the book. Instrument and rod numbers must be given.

Notes should be kept as neatly as possible, and all figures should be clear and plain, so that there can be no possibility of misreading them. Ink or hard pencil may be used. Do not erase an incorrect figure or record, but draw a single line through it, and write the correct entry above it. Do not use separate loose sheets of paper for recording notes; all records must be set down directly in the books, so that there can be no possibility of losing a part of them.

The description of a bench mark should begin directly opposite the entry indicating elevation. Notes should not be crowded, and if two descriptions occur close together, the records for the second mark should be started enough farther down on the left-hand page to clear the description of the first mark.

There are a number of items that should be recorded in addition to the rod readings and elevations. Weather conditions and temperature, details of rod and instrument tests, brief statements of unusual incidents that may affect the results, page cross references at junction points, and other such details form a necessary and important part of the records and should be written on the right-hand page of the



notebook, commencing opposite the entry for the point in the line to which they apply. Every page heading should be filled in with the date and a brief description of the line.

In short, the levelman should remember that his notes are made for the purpose of transmitting information to the office and therefore should be in such shape as to be clearly understandable not only by himself but by others.

Forward the records to the Washington office by registered mail. Field books and bench-mark books should be sent in different packages on different days, so that if one package is lost the other may furnish the data for the line. It is very unlikely that both packages would go astray. A letter or card should also be sent, stating that the books have been mailed.

#### DESCRIPTIONS OF BENCH MARKS AND USEFUL ELEVATIONS

Complete descriptions of all bench marks and useful elevations must be entered in the field notebook and should be copied in the description book (9-916) at the end of each day's work. A comprehensive sketch should be made in both notebook and description book showing the correct position of each bench mark in relation to near-by objects, such as streets, roads, and railroads, and indicating by arrows the direction of the line that is being run and the true north. Such a sketch must accompany the description of every permanent bench mark. Sample pages of the field notebook and bench-mark description book are given on pages 135 and 136.

Descriptions are of the greatest importance in all level records, and the levelman must therefore take particular care to make them comprehensive, concise, clear, neat, and legible and to arrange them in proper form for publication. The items of the descriptions should be written in the following order:

1. Name of the nearest post office, town, village, or other well-known locality, with direction and distance from it to the bench mark, in miles and tenths; or the township, range, and section in which the bench mark stands, with direction and distance from the nearest corner. When a new reference point is cited in the description give the distance to the former point as well as to the new one, thus affording data for total mileage.

2. Position with reference to buildings, bridges, mileposts, and streets or road corners; if along a road, state on which side. Give compass directions; do not use "right" or "left."

3. Description of object on which the bench mark is placed, such as boulder, tree, or concrete post.

Items 2 and 3 should be written in direct (uninverted) form. Items 1, 2, and 3 answer the question "Where?" and should be followed by item 4, which answers the question "What?"



4. Nature of the bench mark—tablet, chisel mark on rock, copper nail with washer, iron pipe, etc.—and how marked or stamped; the object on which the figures of elevation are painted should also be named.

Old bench marks to which the line is tied must be fully described and shown on a sketch, and the old elevation and source of information must be given.

If a previously set transit-traverse mark is used for a bench mark, the description must be the same as the traverseman's unless that is found to be erroneous; in that event a correct description must be entered in the description book, and a copy sent to the Washington office.

The levelman who sets a permanent bench mark should make a pencil copy of his description on a loose sheet of paper to transmit to the traverseman if one follows. This should be done each day, so that the set is up to date when the line is finished.

Descriptions should be written in the order in which the bench marks occur along the line. If standard bench marks are not established when the line is first run, spaces should be reserved for them in their proper order in both the field notebook and the description book. A brief description of the line should be given as a page heading, and when the direction of the line is changed the distance and direction from the reference point along the route of the line should be given, not the air-line distance and direction. For example, if the line runs in a general easterly direction for 6 miles from the reference point and then changes to a northerly direction, a bench mark set 3 miles beyond the bend should not be described as "about 7 miles northeast of" the reference point but as "6 miles east, thence 3 miles north from."

If any correction is made to the field-book elevations when they are copied into the description book, a full explanation should be written in the description book, including the data warranting the change.

A neat and legible diagram of all lines and circuits must be made on a page near the back of the description book. Boundaries of quadrangles should be shown, and if the area is covered by public-land surveys the position of each line with reference to township and section lines should also be shown. The direction in which each line was run must be indicated by arrowheads placed on the line, and the number of the page on which the record was made must be placed at the beginning and end of each circuit and line; the location of all permanent bench marks must be indicated by crosses; and all towns and villages and the crossings of the larger streams must be shown. The records in the description book are incomplete without this diagram.

## CLOSURES AND RERUNNING

Formulas are given for the limits of error and closures on the different types of lines hereinafter described. If a circuit fails to close within the specified limits, and if the levelman is in doubt what to do, he should immediately notify the Washington office, giving details of the line, descriptions of the initial and final bench marks, his rod numbers and tests, and any other information that may enable the office to verify data regarding older lines or to arrive in any way at an explanation of the excessive closure. Rod error is a common cause of failure of field results to close. Meanwhile, if additional lines that will intersect the line of error are contemplated, they should be run by the levelman before he attempts any releveling over the erroneous line. These intersecting lines may show which part of the erroneous line is weak, and that part should then be investigated. If no explanation for the excessive closure can be found either in the office or in the field, the weak link or line should be rerun. This work should be done by a method as accurate as that by which the line was run at first, but in the opposite direction. If the line to be rerun is of the second order and has thus already been run twice, a single additional running, with the same care and refinements as in the original work, will suffice if it checks one of the two former lines. If the line is long it should preferably be rerun by a different levelman. Complete details of all rerunning should appear in the bench-mark description book.

When there is a large discrepancy between two runnings of any section of a line, a third running of the section is required in order to prove whether it is the first or the second running that is in error. If the third running agrees within the permissible limit with one of the other two their mean shall be used to carry forward the elevation, the discordant one of the three being eliminated.

For example, suppose a circuit from A to B, with seven intermediate bench marks, closed 1 foot out of limits. Begin at B and rerun back toward A to locate the error. Between bench marks B, 7, 6, and 5 the new line checks with the old, but between bench marks 5 and 4 a divergence between the two lines is found which is nearly equal to the closure error. Continue the line, however, to another bench mark (3) to verify this divergence. When it has been verified go back and rerun the line in either direction between bench marks 4 and 5, where the large divergence occurred. If a large discrepancy is found on rerunning a line between any two bench marks, that part of the line must be run a third time to discover which running was in error and to obtain two records that are in close agreement.

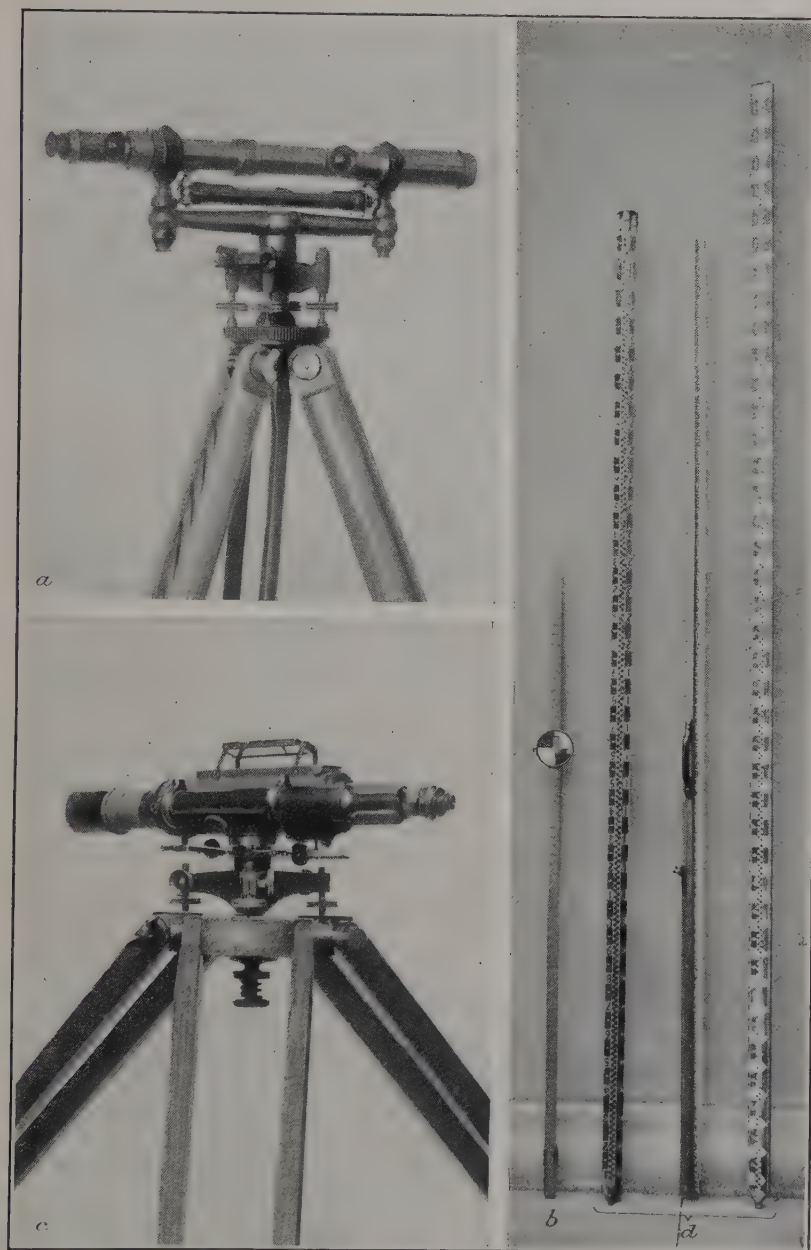
If as the rerunning progresses no error approaching the allowable closure limits is found between any two bench marks but the divergence between the new and old lines continues, the error is shown to be cumulative, and in that case the rerunning must be continued to the end of the circuit or loop. If the closure is then satisfactory no third running of such a line is necessary. Before releveled any part of a large circuit on account of a large closure error, it is best to run a cross line if the additional bench marks will be useful or the probable amount of releveled thereby be reduced. This will localize the error in a smaller circuit.

Every effort should be made to have all lines closed satisfactorily before the leveling party leaves the locality, as faulty lines may prevent the adjustment and publication of the work. Lines may fail to close on account of error of two kinds—gross errors and slight inaccuracies that accumulate through the line. Methods of minimizing the cumulative errors are discussed in the detailed instructions for the different kinds of work (pp. 131–133). Gross errors are usually due to carelessness, but occasionally even the most careful and painstaking man may make such an error. Failure to close a line may perhaps be due to no fault of the levelman. Sometimes the starting or ending elevations may be incorrect, or there may be other understandable causes for the failure. In any case, if the levelman has been conscientious, painstaking, and careful, he need feel no embarrassment in occasionally failing to close a line and in recording the circumstances fully in his books. Field notes should not be erased or altered, even to effect neatness in the books. Alteration to disguise or conceal an error or falsifying the records in any manner is evidence of fraud and of course will not be tolerated. To avoid all question, therefore, it is best never to make an erasure of any sort in a field book, as any evidence of such a change will immediately arouse suspicion when the notes reach the computer.

#### CARE OF INSTRUMENTS

*Responsibility for damage.*—The effectiveness of instruments may be maintained by proper care in handling and transportation. This care is highly necessary, and everyone who is intrusted with instruments is expected to see that they receive such care and protection that when returned to the custodian they will be in fit condition for further use. Damage or injury to leveling instruments is often the result of carelessness or negligence of the levelman or the rodman. When evidence of such carelessness is discovered any expense incurred for repairs will be charged to the person who is responsible.

*Level.*—When the level is not in use it should be kept in its wooden case, with the top fastened; that is the only way to insure it against being tampered with or knocked over.



INSTRUMENTS USED IN LEVELING

*a*, Wye level; *b*, New York level rod; *c*, prism level; *d*, yard rod





When the level is being transported to and from work in the field it should not be subjected to bumps or jars from riding unprotected on the floor of the conveyance. The safest way to carry it is in the lap, but if it is carried in its case the box should rest on a padded support. It should not be unnecessarily exposed to damp or rainy weather and must be kept in a dry place at night.

When the level is shipped by express it must be securely packed in its case with paper to protect it from jarring or its parts from shaking loose. Old newspaper makes excellent packing; excelsior or hay must not be used for this purpose. The wooden case containing the level must be packed inside another box.

*Rods.*—It is very important, particularly for areas where differences of elevation are considerable, that an accurate value for the length of the leveling rod be determined not only from tests by the Bureau of Standards but also from field tests by the levelman. At the beginning of each field season and at least every two weeks thereafter the levelman should make several measurements of each leveling rod he is using, with an invar test tape or a tested steel tape kept for that purpose, and record in proper order in his notebook the mean of the result to thousandths of a foot for each graduation tested. State definitely the length of the rod interval tested, and give the rod number and test tape number. The tape should be held as nearly as possible at the tension for which it is tested, which should be 10 or 15 pounds. If an ordinary steel tape is used, special attention must be given to the reading and recording of the temperature. The comparisons should be made under the same conditions as those prevailing when the rod is in use. As invar strips are easily damaged by bending or by coiling too tightly, they must be handled carefully. Corrections for rod error need not be made in the field except in a rough way when needed to check circuit closures.

A levelman is responsible for the safety of the rod; he must see that the rodman takes proper care in handling and transporting it in the field. Particular care must be exercised not to expose the face of the rod to anything that may deface or mar it. The face of the rod must not be laid on the ground nor exposed unnecessarily to the weather. When not in use the rod must be kept in its canvas cover, and it must be stored in a dry place at night. When it is being transported to and from work it must be carried in its case and must be fully protected from rubbing or blows. When a New York rod is shipped by express it should be either packed in a box or fastened to a board extending 2 inches beyond each end. The target should not be removed from the rod but should be fastened securely to a flat board and protected with hay or excelsior.

If the rod is not shipped in a box its face should be thoroughly protected and the entire rod should be wrapped in canvas or burlap. Precise rods must always be shipped in the boxes made especially for them.

Neither level nor rod should be left overnight in the care of a person not connected with the Geological Survey merely to avoid the inconvenience of taking them to headquarters.

A levelman who is careful with his instrument will be careful with his work.

*Minor repairs.*—Each levelman should provide himself with a few simple tools and supplies, such as a small pair of pliers with side wire cutter, screw drivers of two sizes, small flat and round files, a spool of soft copper or brass wire, some assorted brass nails and screws, a bottle of oil, a bottle of liquid shellac, spider web, and plaster of Paris, all of which may be used for minor repairs to the instruments.

Field work should not be delayed by sending an instrument away for repair if the levelman can possibly repair it himself. Even crude repairs may often be made to serve until a new instrument can be procured. A piece of hardwood may be used temporarily to replace a screw that is accidentally broken.

In leveling or adjusting an instrument tighten screws to a snug bearing only, using but little force.

If it becomes necessary to separate the two lenses that make up the object glass, which should seldom be done, insert three pieces of paper about one-eighth inch in length, equally spaced, near the edge when putting the lenses together. If this is not done color rings will probably form and interfere with the vision.

### GRADES OF WORK

The permissible limits of error in the three grades of work required in leveling are indicated below.

First order	-----	{	----- feet..	0. 017 $\sqrt{\text{length of section in miles}}$
			millimeters..	4 $\sqrt{\text{length of section in kilometers}}$
Second order	-----	{	----- feet..	0. 035 $\sqrt{\text{length of section in miles}}$
			millimeters..	8. 4 $\sqrt{\text{length of section in kilometers}}$
Third order	-----		----- feet..	0. 05 $\sqrt{\text{length of circuit in miles}}$

Whichever grade of work is attempted these limits of error must not be exceeded. The grade of work classed as third order should not be extended more than 30 miles from work of higher accuracy. Second-order lines, double run, must be used as trunk lines for expanding the work over distances too great to be covered by un-

supported lines of third-order accuracy. No standard bench marks should be established on lines less accurate than those of the third order.

### THIRD-ORDER LEVELING WITH WYE LEVEL AND TARGET ROD

#### PERSONNEL AND EQUIPMENT

The level party consists of a levelman; one or two rodmen, one of whom may act as chauffeur and be used to set permanent marks in advance of line; and in some areas a bubble tender. The equipment issued (see pl. 7) is as follows:

- One 20-inch wye level.
- One or two New York rods.
- One or two plumbing levels.
- Two steel turning pins.
- One set dies (figures and letters).
- One pocket compass.
- One 25-foot steel tape.
- One special invar strip testing tape.
- Thermometer.
- Bench-mark tablets.
- Copper nails and washers for intermediate bench marks.
- Cement in cans.
- Two paint cans.
- Level notebooks, 9-903 in black covers to be used by levelman; 9-903A in yellow covers to be used by rodman.
- Bench-mark description book 9-916.
- Two book bags.
- Small cold chisel ( $\frac{1}{4}$  inch).

Other accessories, to be obtained in the field, are as follows:

- One or two hatchets or Boy Scout axes.
- One drill hammer.
- One post-hole digger.
- Two stone drills,  $1\frac{1}{8}$ -inch bit.

#### CHARACTER AND ACCURACY

Third-order leveling should be run as single lines forming circuits wherever practicable; otherwise the lines must be checked by rerunning, preferably in the opposite direction. No work is complete until it is checked in some way. Lines should be connected with near-by bench marks of railroads, cities, highways, and other organizations either by making these marks turning points in the main line or on a spur line leveled twice.

The closure error, in feet, of a circuit should not exceed

$$0.05 \sqrt{\text{length of circuit in miles.}}$$



### READING OF TARGET ROD

Both the levelman and the rodman must read each target setting independently and keep complete separate field notes.

When the target is set for the back-sight reading, the rodman must immediately read the rod and set down his reading in his notebook. He should then bring the rod forward to the levelman without changing the setting. The levelman then reads the rod, recording his result. They must not compare figures until their respective records for a given sight are completed. If the difference between the records exceeds 0.002 foot each must read the rod again before further comparison is made.

When the fore-sight target is set, the rodman must immediately read the target and record his reading. The setting should remain undisturbed till the levelman can come forward and make an independent reading, and he should record the result in his book before making comparison with the rodman's reading.

When a New York rod is lengthened beyond 6.5 feet both the rodman and the levelman must examine the setting of the target as well as the reading of the rod vernier. When the rod is closed they should see that the rod vernier indicates 6.5 feet, not depending on the abutting ends to bring it back to place.

### LENGTH OF SIGHT

The maximum length of sight permissible under the most favorable conditions is 300 feet, except across rivers or deep ravines. In such places reciprocal observations must be made as follows: Just before reaching the river or ravine the levelman should see that all excess in total distance by either fore sights or back sights is eliminated. He should then establish a turning point (A) near the edge of the river or ravine, approximately opposite and level with a point (B) to be established on the opposite side. Next he should test the adjustment of the instrument. Then, with the instrument set up 20 to 50 feet from the point A, he should take a back sight on it and a fore sight on point B. He should then move across the river, set up the instrument 20 to 50 feet from the point B, and take a back sight on point A and a fore sight on point B. The mean of the two elevations determined for the point B will be accepted as correct. For very long sights at least four readings on the distant rod should be made and the average adopted. To minimize the refraction it is advisable to read the rod on the distant sights 3 feet or more above the ground.

### EQUALIZATION OF FORE-SIGHT AND BACK-SIGHT DISTANCES

In order to eliminate instrumental errors and errors caused by curvature and refraction the lengths of fore and back sights should

be equalized at each set-up, but if this is impracticable because of an abrupt change in grade, enough unequal sights to balance should be taken as soon as the grade is passed, before another permanent bench mark is reached and before any change in the instrument adjustment is made. The difference between sums of back-sight distances and fore-sight distances should not exceed 1,000 feet.

If the adjustment of the level is changed before balancing sums, any attempts to eliminate instrumental errors by taking unequal sights to balance former sights are useless.

The failure to balance sights may allow a large inclination of line of sight to affect results if not corrected by the determination and application of a slope factor (C). The levelman should make observations for this factor by the peg method (p. 141) at all places where it is found impracticable to balance the sights. The values of C should be recorded on the right-hand page of the notebook opposite the entry for the point at which they were determined, and reference should be given by page numbers to the computation and the section of the notes to which each factor is to be applied. The application of this factor need not be made in the field.

#### MEASUREMENT OF DISTANCES

Distances may be measured by stadia readings on the rod or by counting rails along a railroad. The distances in miles or feet of both fore sights and back sights must be recorded in the notebooks in the proper columns by both the rodman and the levelman. When stadia distances are used, the reading for distance on the back sights should be taken before and on the fore sights after the level readings are taken, in order to prevent disturbing the bubble.

#### ROD LENGTH AND CLAMPS

Rods must be tested for length as explained on page 129. The long rod clamps and the target clamp should be kept working smoothly so that close settings can be promptly made. The bottom of the rod must be kept clean and free from clinging dirt.

#### PLUMBING LEVELS

Plumbing levels must be used, tested at frequent intervals, and kept in adjustment.

#### TURNING POINTS

The regular steel turning-point pin should be used where no rock or other suitable point is available. When the line is being run along a railroad the higher edge of the rail or a spike may be

used, and the point occupied must always be distinctly cross marked with keel before the rod is held on it.

Care should be taken not to choose for a turning point a sloping surface, on which there is a possibility of the rod slipping to a lower position between sights. The turning point must be firm and free of dirt.

Do not depend on a single stake or pin driven the night before as a starting point in the morning.

#### RECORDING

All level notes must be recorded directly in books 9-903 and 9-903 A. The black-covered books are for the levelman's notes, and the yellow-covered ones are for the notes to be kept independently by the rodman. One set of notes must not be merely a copy of the other. Each set must be taken directly from the rod.

For a given point in the levelman's notes the rodman's notes must be at least two lines lower down the page than the levelman's, and the two men must not turn over a leaf at the same time. Erasures of rod readings with rubber or knife are not permissible; a single line should be drawn through an erroneous record and the corrected figures written above it.

Both the levelman's and the rodman's books must be balanced daily. At the bottom of each page and at the end of each day's work the sums of columns of fore-sight and back-sight readings must be recorded and the difference determined. This difference should agree with the difference between the first and last elevations on the page, and the figures for this page check must not be omitted. The sums of the distance columns should be recorded for each page of notes, also the difference of sums of back-sight and fore-sight lengths and the accumulated excess.

The two sets of notes should be mailed to the Washington office in separate registered packages on different days.

Sample pages of the notebooks are given on pages 135-136.

Date, October 18-20, 1924						Name of line, From quarter corner between secs. 31 and 32, T. 38 N., R. 11 E., east along highway to Salem. John Doe, levelman
Dist. B. S.	Dist. F. S.	Back sight	H. I.	Fore sight	Elevation	Total miles
200	200	4.630	741.508	3.799	736.878	0.00 P. B. M.
195	200	1.885	739.594	10.786	737.709	
165	80	1.890	729.698	6.262	728.808	0.45 T. B. M.
50	150	4.934	728.370	1.039	727.331	
205	200	7.673	735.004	6.240	728.764	
200	210	1.642	730.406	5.678	724.728	
200	200	5.203	729.931	2.931	727.000	1.00 P. B. M.
200	200	8.457	735.457	2.314	733.143	
170	150	10.724	743.867	3.589	740.278	
210	200	4.327	744.605	9.033	735.572	
210	200	1.691	737.363	3.996	732.267	
210	200	9.184	742.451	3.588	738.863	
200	200	6.235	745.098	2.688	742.410	
205	150	2.896	745.306	9.583	735.723	
120	120	2.071	737.704	7.493	730.268	
50	65	.775	731.073	8.561	722.512	
70	55	2.671	725.183	5.078	720.105	Ref. M.
160	185	3.885	723.480	2.921	720.569	
200	190	1.965	722.534	11.323	711.211	1.28
55	205	.916	712.127	11.740	700.357	
3, 285	3, 450	82.154		118.645	736.878	Check.
	3, 285			82.154	36.491	
	165			36.491		

Name of line, From quarter corner between secs. 31 and 32, T. 38 N., R. 11 E., east along highway to Salem. John Doe, levelman

T. 38 N., R. 11 E., near quarter corner on W. side of sec. 32, in NE. angle of crossroads, 10 ft. N. of fence corner; top of iron post, stamped "Prim. Trav. Sta. No. 4, 1919, Ill. 737." (See Bull. 567, p. 75.)

728.9, top of west rail of C., B. & Q. R. R.

T. 38 N., R. 11 E., about 0.13 mile S. of corner of secs. 22, 23, 26, and 27, in SE. corner of crossroads, at fence corner, in root on S. side of a 10-inch box elder tree (marked 727.0); copper nail and washer.

745, top of hill

715, floor of bridge over Canoe Creek.

T. 38 N., R. 11 E., at corner of secs. 26, 27, 34, and 35; 22 ft. N. and 20 ft. E. from T. road to E., inside of N.E. fence corner, top of concrete post, bronze tablet stamped "Prim. Trav. Sta. No. 2, K 1924, Ill. 61 D."

Ref. mark is 240 ft. E. of concrete post, on N. side of road, inside of field fence, in root on S. side of a 3½-ft. cottonwood tree, copper nail and washer.

[NOTE.—The above descriptions are fictitious and do not fit the distance recorded.  
A location sketch for each P. B. M. should be given.]



Record in description book (9-916)

Level No. 57. Rod No. 456. Levelman, John Doe					Line from quarter corner between secs. 31 and 32, T. 38 N., R. 11 E., east along highway via Willow Springs to Orlando, Quadrangle, Des Plains	
Date (1924)	Level book		Miles by route	Elevation by field book (feet)	Description (to be written in publication form; add markings)	Elevation adjusted (feet)
	No.	Page				
Oct. 17	1	1	0.00	774.964	T. 38 N., R. 11 E., near quarter corner on west side of sec. 32, in northeast angle of crossroads, 10 feet north of fence corner; top of iron post stamped "Prim. Trav. Sta. No. 4, 1919, Ill. 775." (Bull. 677, p. 4). <div><div>N</div><div>↑</div><div>X</div><div>↑</div></div>	
17	1	3	3.00	756.646	T. 38 N., R. 11 E., at quarter corner between secs. 27 and 28, 30 feet north and 30 feet east from crossroads; 65 feet west of Lace Church, in top of a concrete post; bronze tablet stamped "Prim. Trav. Sta. No. 1, K 1924, Ill. 60 D." Reference mark, 60 feet west and 25 feet north from concrete post, 55 feet north and 30 feet west from crossroads, in root on southwest side of a 1-foot box elder tree; copper nail and washer. <div><div>Ref.</div><div>B.M.</div><div>X</div><div>X</div><div>X</div></div>	
21	1	8	9.57	616.444	Willow Springs, north corner of Wentworth and Fifth Avenues, in top of northwest end of stone doorstep, 8 feet southeast of west corner of building, on southwest side of Henry B. Koller's brick block; copper bolt headed vertically (U. S. Corps of Engineers P. B. M. 121). (See Bull. 493, p. 81.) 616.503 616.444	
23	1	9	10.22	675.053	Willow Springs, 1.00 mile east of, 100 feet east of T road to south, on south side of road at fence line, in root on south side of a 1-foot haw tree; copper nail and washer (marked 675.1). Orlando, at northeast corner of Main and First Streets, in face of stone water table at southwest corner of Orlando National Bank Building; bronze tablet stamped "627 Ill. 1920." (Note: See Bull. 672, p. 56.) 627.592 Elevation by this line. 627.408 Elevation by Bull. 672	
24	1	25	16.22	627.592		
					Closure error	+ .184

[Columns omitted here are used for computations, comparisons, and corrections.]

[Bench marks should appear in this column at usual 1-mile or 0.5-mile intervals as required by instructions.]

## CAUSES OF ERROR

The use of an instrument that is slightly defective or out of adjustment will cause errors unless care is taken in balancing back-sight and fore-sight distances, which reduces errors of this kind to a minimum. Other causes of error to guard against are unfavorable atmospheric conditions, the settling of turning-point pin or instrument, failure of rodman to hold on the pin, carelessness or roughness in setting rod on pin or in closing the rod, slipping of target or long-rod clamps before a reading of the rod is made, poor adjustment of rod bubbles, refraction when taking a sight too close to the ground, "boiling air," attempting to take sights of excessive length. A levelman must exercise continual vigilance to foresee and avoid conditions or incidents that may impair the accuracy of his line. Do not take a sight over 100 feet in length passing within 2 feet of intervening ground.

Work on third-order lines should not be carried on during high winds or when the air is "boiling" badly, because such conditions will affect the accuracy of the work.

## CONDITION OF INSTRUMENTS

Although all instruments are adjusted and tested before they are shipped from Washington, complaints are sometimes made, even by experienced levelmen, that good results can not be obtained with the levels furnished. The levelman should, therefore, immediately on receipt of an instrument, look it over carefully and thoroughly, and if any parts are lacking or so defective as to preclude an adjustment by him he should immediately telegraph for another level. The adjustment of the level must be tested at the beginning of each day's work and corrected if found materially in error. It must be tested and the necessary adjustments made before taking long sights by reciprocal leveling across rivers or deep ravines. However, though it is desirable to keep the level in good adjustment in order to obtain the best results, unnecessary tampering with the adjustable parts of the instrument should, of course, be avoided.

When the line is being run the levelman should not take it for granted that the level bubble will stay centered while the level is being revolved for fore sight, but he should examine it, and if he finds it off, he should relevel it. An error of even a single division of the scale neglected in leveling up a sluggish bubble introduces an appreciable error in the rod reading on an ordinary sight. However, even though the level may be out of adjustment, satisfactory work can be done if all parts are screwed up snug but not too tight and fore and back sights are kept equalized.

## DEFECTS OF INSTRUMENTS

Any of the following instrumental defects may produce bad results, especially if the sights are not equalized. The remedies are almost self-evident.

1. Glass level vial loose in its case or level-tube adjusting screws loose.

2. Glass level vial defective. Sometimes small crystals collect on the inside of the tube and make the movement of the air bubble sluggish or irregular. When this occurs insert a new vial and be sure to set it with the marked (curved) side uppermost.

3. Object glass loose in its cell or cell partly unscrewed.

4. Cross-wire adjusting-screw threads worn out, or screws too tight or too loose, or cross wires themselves too loose.

5. Tripod points or tripod leg-clamp screws loose.

6. Leveling screws too tight or too loose.

Two other possible sources of error are not so easily found, but fortunately they need seldom be considered:

1. The two telescope rings, which rest on the wyes, may be of different size or of irregular shape.

2. The object-glass slide may be out of adjustment.

If the instrument has either of the two defects last mentioned another instrument should be ordered by telegraph and the defective one returned to the Washington office.

## ADJUSTMENT OF INSTRUMENTS

The customary adjustment of the wye-level should be taken up in the following order: (1) Collimation, (2) motion of object-glass tube, (3) horizontality of thread, (4) eyepiece slide, (5) level-vial direction, (6) level-vial inclination, (7) wyes.

*Collimation.*—Remove all parallax by focusing the eyepiece with the sky as a background until a distinct image of the cross wires is obtained. Loosen and raise the wye clips, focus, and set the intersection of the cross wires on a point, such as a nailhead, 300 feet or more away, revolve the telescope halfway around in the wyes, and note whether or not the intersection of the cross wires moves away from the point. Should the horizontal wire be found above or below the point, bring it halfway back by the capstan-headed screws perpendicular to it. Repeat the operation until it will reverse correctly. Proceed in the same manner with the other wire until the adjustment is complete. Erecting telescopes require a movement of the reticule screws as if to increase apparent error.

*Motion of object-glass tube.*—When the collimation adjustment is perfected for distances of 300 feet or more as described above,

proceed to test it for a distance of 20 or 30 feet, and if coincidence is not obtained after revolving the telescope on the near-by point it is evident that the object-glass slide is out of adjustment. To correct the error remove the bubble tube and the ring near the middle of the telescope and with a screw driver turn the screws, each pair in succession, until the cross-wire intersection will coincide with the near-by point while the telescope is revolved  $180^\circ$  in the wyes. When the collimation is perfect for both long and short sights, replace the telescope ring and the level-bubble tube. This adjustment is seldom required.

*Horizontalty of thread.*—Level the instrument carefully with wye clip pins in place, and select or set some point at the exact elevation of one extremity of the horizontal wire; clamp the spindle and with the tangent motion turn the instrument on its vertical axis until the opposite side of the field of view is reached; note whether or not the opposite extremity of the horizontal wire now coincides with the point selected. If it does not, it can be made to coincide by loosening one vertical and one horizontal capstan-headed screw and turning the reticule until perfect horizontality is obtained. A plumb line on the vertical edge of a building may be used to test the verticality of the vertical wire. Always retest and correct any derangement to the line of collimation which this movement of the reticule may have caused before proceeding further.

*Eyepiece slide.*—The adjustment of the eyepiece tube so that the cross-wires will appear in the center of the field, is not essential to the accuracy of the work but may be effected by means of the screws underneath the ring just back of the cross-wire screws. Loosen one and tighten the opposite one of these screws with a screw driver until the wires appear centered.

*Level-vial direction.*—When the bubble has been carefully centered, with the instrument clamped parallel to opposite leveling screws, loosen the clips and rotate the telescope around its horizontal axis in the wyes about  $20^\circ$  each way from the normal position, making sure that the wyes are free from dirt; if the bubble moves away from the center toward opposite ends alternately, bring it all the way back by the side or azimuth adjusting screws by loosening one and tightening the other. In the ordinary wye level the two rings on the telescope tube that rests in the wyes are assumed to be circular and exactly equal by construction, but if they are not the bubble will run toward the same end when the level is rotated either way from the normal position. Under such conditions an inclination of the line of sight will exist after the usual adjustments are apparently satisfactory, and the only course left open is to treat the instrument like a Dumpy level and to adjust the level to the



telescope by the peg method described on page 141. This is a more direct adjustment and gives a positive useful measure of the inclination of the line of sight.

*Level-vial inclination.*—When the bubble has been carefully centered with telescope in normal position but with clips open, lift the telescope out of the wyes, reverse it end for end, and replace it in the wyes; if the level bubble has moved away from the center bring it halfway back by means of the capstan adjusting nuts at one end of the level tube and the rest of the way by the lower leveling screws. Repeat this operation until the adjustment is perfect, and close the clips.

*Wyes.*—After each of the foregoing tests and adjustments have been made, the wyes can be adjusted. This is done by turning the telescope and level  $180^\circ$  on its vertical axis; if the bubble, which was at first in the center, moves away, bring it halfway back by changing the setting of the pair of large capstan nuts under one wye and the remainder of the way by the base screws. This wye adjustment is relatively unimportant and is made more as a matter of convenience than of necessity.

#### SPECIAL ADJUSTMENTS

All instrumental errors may be compensated in each set-up by the exact equalization of back-sight and fore-sight distances, but as this can not always be done it is important to know the amount of error introduced when a balance is not maintained. The level and collimation adjustments are the most important of the regular wye-level adjustments, but a large deviation of the line of sight from parallelism with the level vial, due to unequally worn or deformed rings or unequal pressure of clips, may exist and will not be revealed by the usual adjustments. Information as to this deviation is desirable, however, and should be obtained, in order to show the condition of the instrument and to take it into account when sights have not been well balanced. The existence of this deviation is ascertained by means of the peg-method test for the determination of C.

*Peg-method test for determination of C.*—Use two turning points about 300 feet apart and at nearly the same elevation. Set up the level about 30 feet from one point, and with the bubble centered take readings on the rod for both points. Repeat the operation from a set-up 30 feet from the other point. From these readings and distances determine the inclination of the line of sight per 100 feet of distance, which is the constant C. The value of C is expressed by the following formula:  $C = (\text{sum of near-rod readings minus sum of distant-rod readings less } 0.004 \text{ feet for curvature and refraction}) \div (\text{difference between sums of long and short sight distances} \div 100)$ . Example:

Distant rod		Differ- ence	Near rod	
Distance	Readings		Readings	Distance
299	<i>Turning point A</i> 4.520	0.256	<i>Turning point B</i> 4.264	35
298	<i>Turning point B</i> 3.580	.282	<i>Turning point A</i> 3.862	32
597 67	8.100 .004		8.126 8.096	67
530	8.096		+.030	

$$+0.030 + 5.30 = +0.0057 = C.$$

This is equivalent to an error of 0.017 foot on the rod at a distance of 298 feet ( $0.0057 \times 2.98 = 0.017$ ), which is the amount that would be required to raise the line of sight on the distant rod to make it level.

The computation should be carried to the fourth decimal place, and the parts of the notes to which the value determined applies should be plainly indicated. The value of C should be recorded on the right-hand page of the notebook opposite the entry for the point at which the test was made, and a page reference to its computation should be given.

*Peg-method adjustment.*—The adjustment by the peg method is necessary when the rings are unequally worn or deformed and is a direct method of bringing the line of sight parallel to the vial. It is accomplished by taking up the amount of error disclosed in the peg-method test by raising or lowering the reticule while keeping the bubble centered. The reading on the rod at the distant point corresponding with a level line of sight at the instrument is found by increasing or decreasing, according as the constant C is plus or minus, the last reading made on the rod so situated by the product obtained by multiplying the distance to the rod in feet by C divided by 100. If, after making the usual wye-level adjustments for level and collimation, a peg-method test reveals so large a value for the constant C that this adjustment is required, the usual collimation adjustment should be abandoned and this peg-method adjustment used instead. This will leave the level-vial and wye adjustment undisturbed and repeatable and take up the other instrumental errors by moving the reticule. In the prism level the error is taken up more conveniently by the vial adjustment screw, as the level is not reversible. If an adjustment is made after a value for C has been determined a new determination is required.

## THIRD-ORDER LEVELING WITH PRISM LEVEL AND YARD RODS

### PERSONNEL AND EQUIPMENT

A prism-level party consists of one levelman, two rodmen, a recorder, and a general utility man. The instruments and outfit (see pl. 7) consist of the following:

- One prism level.
- Two yard rods, each to have plumbing level and thermometer attached.
- One steel tape (25 feet).
- One special invar testing tape.
- Two steel turning-point pins.
- Two rawhide mallets.
- One pocket compass.
- One Locke level.
- One set of dies (figures).
- Bench-mark tablets or posts.
- Copper nails and washers for temporary bench marks.
- Cement, paint can, keel, and other accessories.
- Two book bags.
- Prism level notebook 9-940 or 9-940A.
- Bench-mark description book 9-916.

### CHARACTER AND ACCURACY OF LINES

Third-order levels executed with a prism level ordinarily need be run in one direction only but must be checked by closing circuits or releveled or otherwise. Circuits must close with an error in feet not exceeding  $0.05 \sqrt{\text{length of circuit in miles}}$ . Steps to be taken if the closure is in excess of this amount are explained in the first part of these instructions (p. 127).

### GRADUATION OF ROD

The rods used are graduated to yards, tenths, and hundredths and are read by estimation to thousandths. Each yard has a different and distinctive color, which must be recorded for each reading. One edge of the rod has also graduation in tenths of feet, numbered, for use as a check on yard readings, and some rods have "double yard" graduations to be used as a check. These rods are of the "self-reading" type and have no targets.

### METHODS OF OBSERVATION

Third-order lines of levels may be run in two ways with the prism level—by reading all three horizontal cross wires on the rod, or by reading the middle one only. The three-wire method gives more accurate results and makes available a greater number of checks

against errors, but the keeping and computation of the field notes are somewhat more cumbersome. The one-wire method has a slight advantage in speed and simplicity.

### THREE-WIRE METHOD

In the three-wire method the program at each set-up is as follows: After the tripod is firmly set and the clamp screws tightened, level approximately by the circular level, which has been adjusted by comparison with the long level. Point the instrument toward the back rod and clamp; bring the level bubble to the center of the tube by means of the micrometer screw. Read on the rod and, first, call off the color initials for the lesser and greater extreme readings; second, call yards and tenths for each wire, taking the smallest reading first; third, repeat and read yards, tenths, hundredths, and estimated thousandths; fourth, for additional check on the yard number, read the middle wire on the tenths of feet scale on the back of the rod, estimating and recording to hundredths of a foot. When the recorder has checked the back sight he signals the rear rodman to come ahead. Meanwhile the levelman sights the front rod and takes the fore sight as soon as the recorder has checked the back sight but does not move his instrument until the recorder has also checked the fore sight. The front rodman remains at his turning point, guarding it carefully against disturbance. The levelman moves forward to his next set-up, and the free rodman advances to a new turning point. Rodmen should never exchange rods.

Prism-level notebooks (9-940A) should be used when readings are to be made on all three cross wires. The horizontal lines in these books are in groups of four, and the bottom line of each group is red. Each group is intended to cover a single set-up of the instrument, the back sight on the left and the fore sight on the right. Sample pages of level notebooks are given opposite page 144.

The seven columns on the left-hand side of the book, from left to right, are used as follows: In the left part of column 1 are written the yard color initial of the first and last yard readings and the check reading in hundredths of a foot, the last figure being estimated; in the right part of the same column are placed the three yard readings to thousandths of a yard. In column 2 are given the interwire intervals, found by subtracting the least yard reading from the middle and the middle from the largest. If the three cross wires are equally spaced these two interwire intervals should be within 0.002 or 0.003 yard of being the same, thus giving a check on the yard readings. The wires are so spaced that either one of these intervals, as read on a yard rod, will give a stadia distance to the rod in feet—that is, the interval between the middle wire and



either one of the others will subtend 0.1 yard on the rod for every 100 feet of distance to the rod. The continuous accumulating sum of the interwire intervals between the least yard reading and the middle is carried along from set-up to set-up, starting with zero at each permanent bench mark. This sum of back-sight distances, which is written on the fourth line of each group, may then be compared at any time with the sum of fore-sight distances to see how nearly fore-sight and back-sight distances agree. If the continuous sum of interwire intervals is not carried along in this manner the net excess of the page sums of interwire intervals for one column down to the bottom of each page should be placed at the top of the same column on the next succeeding page. Added together these amounts give the distance run from the last permanent bench mark. Column 3 is for the sum of the three yard readings, which is equivalent to the mean of these three readings converted to feet, and it is checked by the readings in hundredths of a foot taken on the back of the rod. Column 4 is used for H. I. and elevation.

The space above the short black line is for the H. I., and that below the line for the elevation. Columns 5, 6, and 7 are for the fore sight, and are used in the same way as columns 3, 2, and 1, respectively. Thus in each fore sight or back sight there are three independent checks: The color initial checks the first figure of the yard readings, the inter-wire intervals check the difference of the yard readings, and the foot reading on the back checks the sum of the yard readings. These three checks must be made for the back sight before the back rodman moves his turning-point pin, and for the fore sight before the instrument is disturbed. When a bench mark is reached, the page sums of columns 3 and 5 should be completed, and the levelman should also make corresponding sums of the foot readings in columns 1 and 7 as a check. Also, either the recorder or the levelman should add the middle-wire yard readings in both columns 1 and 7, and multiply each sum by 3. This will check the sums for columns 3 and 5 if the algebraic sum of the discrepancies of the inter-wire intervals is considered. If column 4 is filled in, the usual page check should be made, the difference of the sums of columns 3 and 5 being used to check the difference of the first and last elevations on the page. Show all such computations in full.

If in the body of the page the record is reached of a point for which the elevation is to be computed, the H. I. and elevation must be entered throughout the page. Otherwise it is permissible to carry the elevation through the page by means of the totals of columns 3 and 5, using the total of column 3 as a back-sight reading to be added to the elevation brought forward from the preceding

page and the total of column 5 as a fore-sight reading to be subtracted from the result of this addition to obtain the elevation to carry forward to the next page.

If a bench-mark description falls in the middle of a page, it is advisable to skip one of the four-line spaces before continuing the notes, thus giving room for distance totals, etc. The bench-mark descriptions are to be written in book 9-916 in the same form as for wye-level results. (See p. 136.)

In using two rods on alternate turning points, give the number of each rod occasionally alongside the record of a fore sight on which it was used.

#### ONE-WIRE METHOD

In the one-wire method rods having the double yard graduation on the back should be used. The program at each set-up is the same as described for the three-wire method, except for the reading and recording. The stadia distance is first read while the instrument is being leveled. Then, by the middle wire only, are read, first, the yard color initial; second, the yard, tenth, hundredth, and estimated thousandth; and third, the "double yard" reading estimated to thousandths. These readings are recorded in field book 9-940. A sample of field notes is given on page 146. The horizontal lines are in groups of two, each group covering one set-up. The upper line of the two should be used for recording the back and fore sights and the H. I. for the set-up. The elevation of the forward turning point should appear by itself on the lower one of the two lines. In column 1 are entered the color initial of the middle wire reading and the distance to the rod in feet, obtained by reading stadia on the rod. Column 2 is for the check reading in "double yards," column 3 for the yard reading, column 4 for H. I. and elevation placed as noted above. Columns 5, 6, and 7 are for the fore sight and are used like columns 3, 2, and 1, respectively, for the back sight. The recorder should mentally multiply each double-yard reading by 2 and compare the result with the corresponding yard reading, thus obtaining a check of not more than 0.001 yard above or below, before the next sight is taken or the turning point or instrument disturbed. The yard readings are used to compute the H. I. and elevation in column 4 through every page. These values are therefore in yards. Computations of bench-mark elevations in feet are to be placed on the right-hand page. The usual page check must be made for every page by comparing the difference of the sums of columns 3 and 5, multiplied by 3, with the difference between the beginning and ending elevations for the page, converted to feet, this computation to be shown in full. The sum of the distances in columns 1 and 7,

converted to miles, is entered to show the total miles from the last permanent bench mark. A two-line group should be skipped before continuing the record after establishing a bench mark. Bench-mark descriptions are written in book 9-916 in the same form as for wye-level lines. (See p. 136.)

### LENGTH OF SIGHTS

The length of fore and back sights should be equalized with the prism level as with the wye level. The maximum length of sight with the prism level is 360 feet except at river crossings, where the mean result of reciprocal observations should be taken between one pair of pegs at nearly equal elevations on opposite banks.

Mount the instrument first near one peg and then near the other so that the center wire will fall near the middle of each rod; if the distance is too great to read the three wires, use improvised targets of cardboard held in place by rubber bands or some other simple device, and make several settings by raising and lowering them an equal number of times. Rodmen should be provided with field glasses if necessary to read signals. From bench marks on each bank the elevation of the adjacent water surface should be determined as an additional check.

### MEASUREMENT AND USE OF RODS

Testing of the rods in the field for length is very important. On wooden yard rods small metal plugs are set into the faces at intervals, each bearing a fine graduation; these are for use in testing the rods. These tests are made as explained on page 129.

The rods must be kept covered when not in use. The painted sides must not touch the ground. Should difficulty be found in holding a rod steady because of wind, two pieces of bamboo or other light poles, 8 feet long, may be held by the rodman against the rod, so as to make a triangular brace against the wind. Plumbing levels must frequently be tested and kept in adjustment.

### ADJUSTMENT OF PRISM LEVEL

When the work is commenced, and at least once each day thereafter, the adjustment of the level must be tested by the "peg method," either by making two separate set-ups, apart from the line, as described for testing the wye level (p. 148), or by utilizing one of the sights of the line itself, thus saving one set-up. If the latter procedure is used care must be taken not to get the extra



sights confused and introduced into the line, in place of or in addition to the regular sights. To do so would introduce a gross error.

*Peg-method test and computation of C.*—At some convenient set-up, having a full-length fore sight, after the usual back-sight and fore-sight readings have been recorded, copy the fore-sight reading on the right-hand page for use as a long test sight. Set an extra turning point about 30 feet back of the instrument, and read the rod on it for a short test sight. Move the level forward to an extra set-up about 30 feet back of the regular fore-sight pin, and read the rod on it for the second short test sight. The rod is read also on the extra turning point, for the second long test sight. The test sights are now all obtained, and the extra turning-point may be moved, the instrument carried forward, and the line continued as usual from the regular turning point. The two long test sights, recorded one under the other on the right-hand page, and the two short sights, similarly recorded, should be marked "Determination of C." Test sights should be taken in the same manner as the regular sights, three wires or one wire being used according to the way the line is being run.

The constant C, which is a factor of the adjustment correction, must then be determined. It is the sum of readings on near rods in feet minus that on far rods (corrected for curvature and refraction) in feet divided by the difference between the sum of the greater and that of the lesser distances in feet and multiplied by 100. It is the amount, in feet per 100 feet of distance, that the line of sight slopes when the bubble is centered.<sup>1</sup>

When the sum of the readings on the near rods is the greater, the sign of C is plus and the line of sight is too low. Care should be taken to give the proper sign and proper position of decimal points. Curvature and refraction correction for the sum of the long sights in feet is obtained by the formula  $0.00041$  (mean length of long sights  $\div 100$ )<sup>2</sup>. This correction is of such sign as to be always subtracted numerically from the long-sight readings. Examples of the computation of C are given below. In the expression for C by the three-wire method the approximate sums and difference of sums of lengths of long and short sights in hundreds of feet are derived from the corresponding sums and difference of sums of lower or upper thread intervals in yards by moving the decimal point one place to the right.

<sup>1</sup> C as used by the U. S. Coast and Geodetic Survey is the amount of slope, in meters, per meter of total rod intercept or interval between the stadia wires. This is not the same as the amount in meters per 100 meters or feet per 100 feet, because the stadia constant of the levels used by that bureau is 0.003. Therefore the numerical value of C as used under these instructions represents a slope 3.33 times the slope corresponding to the U. S. Coast and Geodetic Survey formula. The difference should be borne in mind when comparing the limits of instrumental error allowed without readjusting. The U. S. Geological Survey prism level stadia constant is 0.006.



*Determination of C for three-wire method*

Long sights			Short sights		
Wire reading (yards)	Interval (yards)	Sum (feet)	Sum (feet)	Interval (yards)	Wire reading (yards)
2.781 3.103 3.426	0.322 .323	9.310	5.893	{ 0.032 .033	1.932 1.964 1.997
1.638 1.956 2.276	.318 .320				3.053 3.082 3.112
		5.870	9.247	{ .029 .030	
		15.180 ° .004			
	.643 .063	-15.176 +15.140	+15.140	.063	
	.580	-.036			

° Curvature and refraction.

$$C = \frac{15.140 - 15.176}{6.43 - 0.63} = \frac{-0.036}{5.80} = -0.0062.$$

*Determination of C for one-wire method*

Long sights			Short sights		
Distance (feet)	Double yards	Yards	Yards	Double yards	Distance (feet)
320 318	1.551 0.978	3.103 1.966	1.964 3.082	0.932 1.541	30 30
638		5.059 ° 15.177 ° .004	5.046 15.138		60
638 60		-15.173 +15.138			
578		-.035			

° Feet.

° Curvature and refraction.

$$C = \frac{15.138 - 15.173}{6.38 - 0.60} = \frac{-0.035}{5.78} = -0.0060.$$

*Peg-method adjustment.*—If the resulting value for C numerically exceeds 0.005, an adjustment should be made by changing the position of the level bubble only, as follows:

Point to a distant rod with the bubble in the middle of the tube and read; move the telescope (by micrometer screw) so as to raise or lower, by an amount derived by multiplying the distance to rod in feet by  $C \div 100$ . This amount is in feet, and it should be reduced to yards in order to set it off more conveniently on the rod. While holding the telescope in this position, bring the bubble to the middle of the tube by raising (or lowering) one end of the level vial with the adjustment wrench. After the adjustment has been made, its accuracy should be tested by redetermining the value of C.

In case the cross wires break and the level-tube adjustment has not been disturbed, insert new spider threads and determine value of  $C$ , as above directed: Compare with the last determination of  $C$ , and adjust for the difference by changing the position of the cross-wire ring only—not the level bubble.

When both level and cross wires have been disturbed the cross wires can be put in proper position by means of improvised wooden wyes in which the telescope is turned while watching a clearly defined point through it, the operation being the same as for the collimation adjustment for a wye level. The length of the air bubble in the graduated level vial can be regulated by means of the air chamber in one end of the glass tube. There is a small passageway in the lowest part of the tube between the air chamber and the main level tube; when one end of the telescope is held considerably lower than the other, with the leveling screws uppermost, if the air chamber end is then the lower, bubbles will be seen rising through the liquid; these added to the large bubble will make it still larger, but if no bubbles appear and the large bubble grows smaller, it indicates that the air chamber is in the upper end. Note the effect at the first trial and act accordingly in future. When the level is being carried from station to station, if the tripod is held nearly vertical the bubble will not change in length.

When leveling up at the beginning of a day's work, set the telescope parallel to two leveling screws and level; turn it  $90^\circ$  and again level. Turn the level  $180^\circ$  and then  $90^\circ$  and test in both positions. If the bubble moves away from the center, bring it half-way back by means of the leveling screws and the remainder by the micrometer screw. When the leveling is perfect adjust the circular level to agree with the other level and note the reading of the micrometer head. The reading should be maintained for the day as nearly as possible to that thus found. The instrument should be so carefully leveled with the leveling screws at each set-up that there will be no material difference between the readings of the micrometer head for fore and back sights; a failure to observe this precaution may introduce uncompensating errors.

#### CARE OF INSTRUMENT

When the level is on the tripod, be sure that the central tripod clamp screw is tight. Keep the telescope off the micrometer-screw bearing while carrying it between stations. Leave the three tripod wing nuts loose when carrying; clamp tight when tripod is in place for work. The micrometer screw should be cleaned and oiled slightly every two or three days.

If the level can not be shaded from direct sunlight by an umbrella when in use, a piece of white cloth or frosted celluloid about 8 inches square may be fastened over the top of the instrument with rubber bands, so as to allow only diffused light to reach the bubble and prisms. While not being used and still on the tripod, the instrument should be set in the shade or a cloth hood thrown over it.

In running lines by the one-wire method there is danger of error through reading the wrong horizontal wire, as all instruments have stadia wires. This possibility may be avoided by revolving the reticule a quarter turn so as to bring the single wire horizontal, and the instrument may be regularly used in this manner. If this is done the rod may be held horizontal for the stadia reading.

### TURNING POINTS

With the yard rod having a hemispherical foot serious errors may result if turning points are taken on the highest point of a rock or nail, as it is difficult to set the rounded shoe in its highest position on such a point. It is better to find a slight nick or depression into which the rounded shoe can settle to a definite position. It is always best, however, to use the regular turning-point pins made for the purpose, wherever there is a chance to drive them into a firm position, even if other hard surfaces are available. A wooden or rawhide mallet should be used to drive the pins. Rods should be set upon the pins gently, so as not to cause them to move or settle.

Certain unfavorable conditions and other causes of error, mentioned on page 137 in connection with work when a wye level is used are also applicable to lines run with a prism level.

## SECOND-ORDER LEVELING

### PURPOSE

Trunk lines of second-order leveling must be run as a framework upon which to base third-order leveling where first-order lines are too far apart to give effective control. These lines should follow as nearly as possible the trunk lines of transit traverse—that is, in lines not over 50 miles apart, so that no point will be over 25 miles from a main control point of second or higher order.

The prime requisites of through trunk lines are accuracy and reliability, and if there is a choice of route, that route should be chosen which will assure the most accurate line rather than the one that may give more conveniently located control for the topographer. The topographer's needs may be satisfied by side loops of a lower

grade. Every effort, both in office planning and in field work, should be made to have these trunk lines run and subjected to a preliminary adjustment, before other work is based upon them. If the trunk line can not be completed in advance, that part of the local work that is run over the route of a planned trunk line should be run in the manner prescribed for the trunk line, thus making a completed link that may later be connected up as a full-weight part of the trunk line.

### PERSONNEL AND EQUIPMENT

For second-order leveling the instrumental outfit and the number of men in the party are the same as for third-order leveling with prism level, except as hereinafter noted. Some refinements of field methods are necessary beyond those required for third-order leveling, in order to insure the required accuracy. The work should be done with the prism level, by the three-wire method.

### CHARACTER, ACCURACY, AND PROCEDURE

Lines must be run independently in both the forward and the backward direction.

The back runnings may start from points on the forward-run line and may be run in such sequence as may be convenient, except that they should not be allowed to lag too far behind the forward running. When the allowable error, in feet, for sections between bench marks exceeds  $0.035 \sqrt{\text{distance between bench marks in miles}}$  the forward or backward measurement is to be repeated until a pair run in opposite directions is obtained between which the divergence falls within this limit. It is especially desirable to make the backward measurement in an afternoon if the forward measurement was made in the forenoon, and vice versa. The observer should make the two measurements under atmospheric conditions as different as possible without materially delaying the work for that purpose.

The last set-up of one running must not be copied nor used as the first set-up of a return running—that is, the instrument must be moved so that an independent reading can be obtained.

Whenever a blunder, such as a misreading of 1 yard or one-tenth or an interchange of sights, is discovered and the necessary correction is applied, the running containing it may be retained, provided there are at least two other runnings over the same section which check it and are not subject to any uncertainty.

The field work must in general conform in the instructions for third-order leveling with the prism level by the three-wire



method. (See pp. 143-145.) In order to insure the increased accuracy required, such precautions as careful rod and instrument tests, equalization of fore and back sight distances, and care in selecting turning points must receive particular attention. Yard rods having graduations on an inlaid invar strip instead of on wood are to be preferred. An umbrella should be provided to shade the instrument when it is set up, and a cloth hood should protect it from the sun when moving from one set-up to the next. The instrument should be very carefully handled and must not be subjected to jars and jolts such as those resulting from riding uncushioned on the floor of an automobile.

### RECORDING

Two sets of field books should be used, one for forward running, which should be kept as an unbroken continuous line, and the other for backward runnings, which should show each section complete and continuous in itself. The sections can not be shown in any particular order in the backward-running books, as their sequence will depend upon the field program adopted in the rerunning. Bench marks need be described only in the forward-running books, but they should receive consecutive numbers and letters, which should appear in the backward-running books also, in order to identify the corresponding marks in the two books. The consecutive numbers should be the same numbers as the identifying numbers stamped on the bench marks. For a supplementary bench mark the same consecutive number should be used as for the next preceding permanent or stamped mark, and consecutive subordinate letters added until the next permanent mark is reached; thus the sequence might be, for example, C-23-1925, 23<sub>A</sub>, 23<sub>B</sub>, etc., C-24-1925, representing permanent mark 23, two supplementary marks following it, and permanent mark 24. In addition to the use of these numbers, careful and complete book and page cross references should be made between the two sets of books, in order that no confusion or doubt may arise in finding the proper pair of runnings for any given section.

### SECTION CHECK

In the forward-running book the difference of elevation should be computed for each section of the line between bench marks, permanent or supplementary, and should appear, with the complete computation, on the right-hand page near the end of the space allotted to the section. The full computation of the difference of elevation obtained by the backward running should appear with the notes for that running, and the difference itself should be brought over into the forward-running book for comparison. These differences must

be in agreement within the limits prescribed above, or it will be necessary to make additional runnings, which should be recorded in the backward-running books, even though the runnings may be in the forward direction.

In running lines with the prism level and the three-wire method the elevation and H. I. need not be computed throughout the page. Differences of elevation should be computed by means of the page totals from bench mark to bench mark, and elevations carried forward by means of these differences, great care being taken to apply them in the proper direction.

#### DESCRIPTION BOOK

Descriptions must be copied into the bench-mark book (9-916) in consecutive order, as in third-order leveling. Field-book elevations, however, are not to be copied into the bench-mark book, but instead the differences between bench marks are to be copied. These should appear in a column to the right of the elevation column, one under the other, beginning just below the line upon which the elevation of the first bench mark is shown. The mean of these two differences is then set down in the next column to the right, and this mean is applied to the first elevation to obtain that for the second bench mark. Thus in the bench-mark book the mean line elevation is carried forward by means of the differences between bench marks. The mean line elevations should then be copied into the forward field book, on the right-hand page above the description of the bench mark to which they apply, and a circle drawn around them to distinguish them from the field-book elevations. If field-book elevations have been carried through in the forward-running book in the usual manner, rough comparison with the mean line elevations will serve to check the proper use of the sign in applying the differences between bench marks.

## Record in description book (9-916)

Level No. 163. Rod Nos. T-32, T-42.				Levelman, John Doe		Line from Troutdale via Highway 24 to Essex. Quadrangle, Newman	
Date (1925)	Level book		Miles by route	Mean elevation (feet) <sup>a</sup>	Differ- ences of elevation (feet) <sup>a</sup>	Mean differ- ences (feet) <sup>a</sup>	Description (in publication form) [Location sketches should also be given]
	No.	Page					
June 2	3F	21	0	428.96	2.330	+2.326	Troutdale, on south side of Corning Street, between High and River Streets, at east front corner of courthouse, on east end of sill of basement window; chiseled square. (Bull. 621, p. 18.)
	3B	41		2.322			
2	3F	22	0.3	431.286	89.451	+89.438	Troutdale, in west corner of Corning and Mission Streets, on east end of second granite step to the main entrance of the First National Bank Building; bronze tablet, stamped "C-32-1921 431." (Bull. 621, p. 18.)
	3B	46		431.278	89.425		
3	3F	23	1.2	520.716	9.087	+9.095	Troutdale, at south city limits, on west side of Mission Street, 100 feet south of center of Lenox Street, on stone curb 17 feet south of fire hydrant; chiseled square.
	3B	44		9.103	9.103		
2	3F	25	2.0	529.811	46.610	-46.594	Troutdale, 2.3 miles southeast of courthouse, opposite junction of road to west, in south root of 24-inch maple tree, about 2 inches above the ground; copper nail. Tree painted "B. M."
	3B	43		46.578	46.578		
2	3F	26	2.7	627.1			South rail at crossing of Denver & Rio Grande Western Railroad.
	3B	42					
2	3F	27	3.3	483.217	60.238	-60.230	Troutdale, 2.3 miles south and 1.3 miles east from, at south corner of small cemetery, just inside the angle of the stone wall, in top of concrete post about 3 inches above the ground; bronze tablet stamped "D-17-1925."
	3B	42			60.222		
4	3F	28	4.5	422.987	20.384	-20.372	T. 5 N., R. 4 W., at quarter corner on south side of sec. 8, on north side of road, at T corner of stone wall, on south projecting corner of lowest corner stone; chiseled square; wall painted "B. M."
	3B	43			20.360		
Out of limits; use third running in place of second.							
5	3F	29	5.7	402.615	17.629	-17.598	T. 5 N., R. 4 W., at east sixteenth corner on south side of sec. 9, 0.25 mile west of cross-roads, on north side of road, on south corner of concrete base of lamp post; chiseled square.
	3B	42		17.567	17.567		
(5)	3F	42	Instrument tested;	7.3	385.017	C = -0.0021.	Essex, at Denver & Rio Grande Western Railroad station at foot of Meadow Street, near east end of main building, at southeast corner of grass plot, in concrete curbing; bronze tablet, stamped "N-20-1902 385." (Bull. 621, p. 28.)
	3B	42					
				Elevation by this line		385.017	
				Elevation by bulletin		385.085	
				Closure		- .068	

<sup>a</sup> These column headings are not printed in book 9-916 but may be added in the space provided for such computations.

## FIRST-ORDER LEVELING

Leveling of the first order has heretofore been called "precise leveling." The net that more or less fully covers the United States, made up of lines run by the United States Coast and Geodetic Survey and other organizations, was last adjusted as a whole in 1912, thus forming a consistent datum for the area, known as the standard datum. In adjusting this net and in fitting subsequent lines to it, work of the first order has been found to require corrections, owing to the distribution of errors in closure, in general less than 0.2 millimeter per kilometer. Work of this type will not ordinarily be done by the United States Geological Survey, but if the necessity for it arises, the detailed instructions given in Special Publication 18 of the United States Coast and Geodetic Survey should be followed.

## COMPUTATION AND ADJUSTMENT OF LEVEL CIRCUITS

### GENERAL CORRECTIONS

In the computation and adjustment of level circuits the notes are first examined for errors in field computations or records. Corrections are next made for rod errors, including those due to changes in temperature; these corrections are products for each difference of elevation by the rod correction per foot. Corrections are applied if required for collimation, curvature, and refraction for unbalanced sights.

### ORTHOMETRIC CORRECTION

On long lines at high elevations a correction is required to take account of the fact that level surfaces at different altitudes are not parallel except at the Equator and at the poles. This correction, which depends on meridional distance, latitude, and altitude, may be found from the following formula:<sup>1</sup>

$$C = \frac{h_m(\phi_n - \phi_s) \sin(\phi_n + \phi_s)}{659,000}$$

in which

C=correction in feet.

$h_m$ =mean height of line in feet.

$\phi_s$  and  $\phi_n$ =the latitudes of the south and north ends of section, respectively.

$(\phi_n - \phi_s)$ =difference of latitude in minutes of arc.

In applying the formula the lines must be divided into sections of not over 100 miles each, and a division should be made where the general direction changes materially. The corrections thus found are applied to the several sections so as to lower the elevations at

<sup>1</sup> Coast and Geodetic Survey Rept. for 1899, p. 875, 1900; Special Pub. 18, p. 49, 1912.  
58515°—28—11



successive division points going northward. Although orthometric corrections may at times lead to apparently absurd results, such as giving a lower elevation for the north end than for the south end of a large lake having no outlet, yet in order to insure agreement between different lines and to obtain results of the greatest theoretical accuracy, they must be applied if appreciable.

After all the foregoing corrections are made to the original results, the remaining closure errors are those which are to be removed by adjustment.

#### ADJUSTMENTS OF FIRST-ORDER AND SECOND-ORDER LEVELING

The net of lines in the United States of the first and second orders of accuracy run prior to 1912 by various organizations was adjusted by the United States Coast and Geodetic Survey and is described in that organization's Special Publication 18, "Fourth general adjustment of the precise-level net in the United States and the resulting standard elevations." By that adjustment the previous general adjustment of 1907 was held fixed for points east of an imaginary line joining Shreveport, La.; Little Rock, Ark.; St. Louis, Mo.; Savanna, Ill.; and Marquette, Mich.; and the portion of the 1907 net west of that line was readjusted to include the orthometric correction and additional lines. The elevations thus derived are assumed to be standard elevations and are expected to be held fixed. The lines subsequently added to the net have been merely fitted in by prorating the closure error. New lines will be similarly treated except that if several connected new lines are considered jointly, a special computation for the new junction points will be made before the errors of each new link are distributed.

#### ADJUSTMENT OF THIRD-ORDER LEVELING

All adjustments of third-order are to be made in the Washington office in the bench-mark description book (9-916), in which abstracts from the field books, which include the description and elevation of each bench mark as determined by the levelman, are written by him in regular order for each line as run.

All the level lines associated with one another should be considered at one time, and in order to obtain a better comprehension of their arrangement they should first be plotted on the office progress maps as accurately as possible, and from these maps tracings should be made on paper, to be used in the adjustment and later filed with the description book as part of the record. The diagram should show the approximate relation of all the lines, including the first-order or previously adjusted lines forming the base of the system, and the

work of different grades or different men should be represented by different-colored inks or pencils or in some other manner, a suitable explanatory legend being attached. The names of a sufficient number of towns should be given to identify the location readily, and beside each line reference should be made to the page in the description book where the bench-mark elevations for that line are given. On each line a  $\succ$  is to be placed to show the direction in which it was run. For small areas the diagram of routes prepared by the levelman in the description book will probably answer in place of the tracing.

The field notes should be examined to see whether the work was in accordance with the instructions; whether fore and back sights were equalized, rod readings properly summed, balances checked, and elevations properly copied from page to page. The entries in the description book should be systematically checked to see that all elevations, including those at starting, junction, and closing points, and all breaks and second runnings are properly copied. Where two runnings of equal weight are made over one course, the mean result should be accepted for adjustment and written with the appropriate statement in a separate column, the divergence being given alongside.

Before proceeding further the rod and orthometric corrections, if considerable, should be applied as explained on page 155.

At each junction point on the diagram should be written the difference between the recorded elevation by some one of the lines and those recorded in the description book for each of the other lines for the same bench mark, with an arrow alongside and plus or minus signs added to indicate that the elevations as recorded by these lines are greater or less than the selected elevation. Also, as an additional aid in the adjustment, the closure error for each circuit should be written in the center of its position on the diagram, the sign being computed in counter-clockwise order. Next ascertain by inspection of the diagram which of the unknown junction points may be determined with the greatest apparent accuracy or by the greatest number of independent lines. From three or more lines connecting this point with the points of known elevation obtain three or more possible corrections to the recorded elevation for one of the lines. Estimate and record relative weights for these corrections, the weights to be based on the reciprocals of length, class of leveling, instrument used, number of times leveled, and relative standing of observers if two or more are involved. Weights should not be influenced greatly by closure errors. If corrections from different sources are computed partly through a common line the length of this part of each route should be doubled in fixing the weight of each correction.



venient number—as 13 in this example—by the computation distances 13, 5, and 10 each in turn, obtaining 1, 2.6, and 1.3 for the weights of the respective lines. These weights are each to be multiplied by the corresponding assumed corrections 0,  $+0.06$ , and  $-0.12$ , giving products of 0,  $+0.16$ , and  $-0.16$ . Divide the algebraic sum of these products by the sum of the weights (4.9); the quotient will be the weighted correction; this is 0 for the point in question, but as there is another line to this point which has not been considered this correction must be accepted as preliminary only. The foregoing data may, if desired, be assembled in tabular form, thus:

From point—	Miles	Weight	Correc- tion	Weight × cor- rection
A-----	13	1.0	0.000	0.00
D-----	5	2.6	$+ .060$	$+ .16$
H-----	10	1.3	$- .120$	$- .16$
Sum----	-----	4.9	-----	.00

The preliminary correction for point B is now taken as 0, as found from three lines, two lines from A and one from E, and a preliminary correction of  $+0.02$  foot for I can be obtained by taking a proportionate part of the closure error at E (one-fifth). Junction point F depends for its elevation on values from several lines. The corrections from E, B, and I are, respectively, 0.00,  $-0.32$ , and  $-0.26$ ; the corresponding distances are 12, 10, and 26; the weights 2.2, 2.6, and 1.0; the resulting preliminary correction for F is  $-0.19$ . A final value for E may now be found from B, D, I, and F, to include the effect of F, and by the foregoing method it is found to be  $-0.03$ . G is found from lines from B through C, F, F through C, F through J, and I, with the computation distances 38, 7, 44, 28, and 38, respectively; in this case the distances C to G and J to G, which are common to two lines, should be doubled in order not to give them undue weight. The final corrections to the various selected elevations are now found in a similar manner, the computations for B, I, and F being repeated to obtain the effect of the additional lines, and are as follows: B, 0.00; C,  $-0.30$ ; E,  $-0.03$ ; F,  $-0.18$ ; G,  $-0.37$ ; I,  $+0.02$ ; and J,  $-0.19$ , two places of decimals only being used for junction points. Each of these corrections is placed in a rectangle on the diagram near the point to which it belongs.

After the corrections for the junction points are fixed, corrections proportioned to the distance are found for intermediate points along the several lines.

For high altitudes the orthometric corrections (see p. 155) should be applied before adjustment.



Lines on which the closure error is over the permissible limit should not be used in adjustment unless they are indispensable in making the best approximation from existing data. Such an adjustment must be regarded as preliminary, pending releveled, and so used for map control. Elevations that are suspected to be grossly in error must not be published unless the data are urgently needed and a caution as to their probable error is expressed.

The computer should report to the division engineer in writing any failure on the part of the levelman to comply with instructions; he should also report all circuit-closure errors in excess of the allowable limit. A copy of these data should also be written on the last inside page of the bench-mark book.

## E. TOPOGRAPHIC MAPPING

By W. M. BEAMAN

### CHARACTER OF TOPOGRAPHIC MAPS

*Definition of a topographic map.*—A topographic map is a representation on paper that is designed to portray certain selected features of a section of the earth's surface plotted on some form of projection and to a certain scale; that primarily depicts the relief of the country mapped but shows also its drainage and cultural features; and that delineates all features in true latitude and longitude and therefore all parts in a rigidly correct relative position. A reproduction of a part of a topographic map is shown in Plate 17.

*Quadrangles.*—The topographic maps of the United States Geological Survey are designed to constitute a topographic atlas of the United States for an engineering and geologic base. For the purpose of this atlas the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. Each sheet of the atlas is a map of some quadrangle. The quadrangle maps are printed on paper of approximately uniform size, about  $16\frac{1}{2}$  by 20 inches, and the maps themselves are about  $17\frac{1}{2}$  inches long and 12 to 15 inches wide according to latitude.

*Field and publication scales.*—Standard quadrangle maps are published on different scales, which have been selected as best adapted for use in the development of different parts of the country. The difference in scale involves a corresponding difference in the size of the area represented. The relation between the field and publication scales of Geological Survey maps and the area represented is shown in the table below.

*Relation between scale of maps and area represented*

Size of quadrangle	Field scale		Publication scale		Area of quadrangle (square miles)
	Fractional	Feet to 1 inch	Fractional	Miles to 1 inch	
1° by 1°	1:192,000	16,000	1:250,000	° 4	3,200-4,200
30' by 30'	1:96,000	8,000	1:125,000	° 2	800-1,050
15' by 15'	1:48,000	4,000	1:62,500	° 1	200-262
7½' by 7½'	1:24,000	2,000	1:31,680	½	50-66
	1:31,680	2,640			

° Approximate.

About 98 per cent of the topographic maps prepared by the Geological Survey have been published on one or another of the four scales listed above.

The large range in quadrangle areas is due to the convergence of the meridians toward the pole; the areas given represent the differences (in round numbers) between the area of a quadrangle near the Canadian border and one in southern Texas or Florida. (For areas of quadrangles in different latitudes see Bulletin 650.)

Standard topographic surveys for the United States proper and the resulting maps have for many years been divided into three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to irrigation, reclamation of swamp areas, or mineral development—are made with sufficient accuracy to be used in the publication of maps on a scale of 1:31,680 (1 inch = half a mile), with a contour interval of 1, 5, or 10 feet.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient accuracy to be used in the publication of maps on a scale of 1:62,500 (1 inch = nearly 1 mile), with a contour interval of 10 to 50 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, are made with sufficient accuracy to be used in the publication of maps on a scale of 1:125,000 (1 inch = nearly 2 miles), with a contour interval of 20 to 100 feet.

A scale of 1:31,680 is used instead of a scale of 1:31,250 (half of 1:62,500) because all the township plats of the public-land surveys of the General Land Office have been made on the 1:31,680 scale, upon which 1 mile is represented by exactly 2 inches.

Some areas are surveyed on special scales for special purposes, as for mineral, power, or urban development and special military use. Among such scales are 1:24,000, 1:20,000, 1:12,000, and 1:10,000, and the field and publication scales are in general identical. In the early days of the Geological Survey maps of large areas were published on the scale of 1:250,000, but now this scale is used for reconnaissance maps.

*Projection.*—In mapping large areas the engineer is confronted with the problem of representing accurately on the plane surface of a map the details that exist on the earth's spherical surface. As it is impossible to do this exactly, he must resort to the use of some convention that will represent the earth's surface with the least distortion. The systematic drawing on a plane surface of lines that represent reference lines on the spherical surface of the earth is called a map projection. There are many systems of projection, each of

which fulfills certain desirable conditions but none of which is ideal. The choice of the proper projection to use for a certain map is not always easy but depends largely on the extent of the area to be represented and on the use to which the map will be put. The best treatise on map projection published in English is United States Coast and Geodetic Survey Special Publication 68, "Elements of map projection."

The topographic engineer needs a projection which is simple in construction, which can be used to represent small areas on any part of the globe, and which, for each small area to which it is applied, preserves shapes, areas, distances, and azimuths in their true relation to the surface of the earth. The polyconic projection meets all these needs and was adopted for the standard topographic map of the United States, in which the  $1^\circ$  quadrangle is the largest unit (fig. 4) and the  $15'$  quadrangle is the average unit (fig. 5). Misuse of this projection in attempts to spread it over large areas—that is, to construct a single map of a large area—has developed serious errors and gross exaggeration of details. For example, the polyconic projection is not at all suitable for a single-sheet map of the United States or of a large State, although it has been so employed. Its greatest advantage lies in the fact that it represents a small area on any part of the earth's surface just as well as one on any other part.

The polyconic projection takes its name from the fact that it is based on the development of a large number of cones conceived to be tangent to the spheroid at each parallel of latitude to be represented on the map. It has been computed for every minute of latitude from  $0^\circ$  to  $90^\circ$ , and existing tables make its construction very easy. It was devised by Ferdinand Hassler, the first superintendent of the United States Coast and Geodetic Survey, and has been computed by that bureau. The theory of the projection and tables for its construction are given in Coast and Geodetic Survey Special Publication 5.

In this projection a central meridian is drawn as a straight line, and the intersections of the parallels are spaced true to scale along this central meridian. Each parallel is then laid down separately by means of a cone whose base is tangent to the earth's surface at that parallel, with the vertex of the developed cone on the extension of the central meridian. The arcs of the parallels thus drawn are subdivided to true scale, and the meridians are drawn through these subdivisions. As a result the central meridian is shown as a straight line, and theoretically all other meridians are shown as curves. As the meridians and parallels nowhere intersect at right angles, except along the central meridian, and as all the other meridians are drawn as curves concave toward the central meridian, it is theoretically impossible to fit together in a row east and west two maps, each of which is



drawn on its own polyconic projection, as their joining edges are curved in opposite directions. However, in practice and within certain limits these conditions do not exist. It is impossible for a draftsman or an engraver to draw the limiting meridians of a  $1^{\circ}$  or smaller quadrangle within the latitudinal limits of the United States other than as straight lines. Therefore, a row of maps east and west will join perfectly, although as the north edge of each map is shorter than the south edge the row will form a curve. A tier of maps north and south will also join perfectly. Theoretically, there will be small gores between the edges of each east-west row of maps and the next row to the north or south, but in actual practice the distortion of map paper due to changes in atmospheric conditions is greater than the error of joining, so a moderate number of maps—say five or six each way—can be joined as perfectly as any maps can be joined. Seldom, if ever, will a map user wish to join more than five or six quadrangle maps in any direction. The size of tables or wall space makes further extension impracticable, so that the theoretical weakness of this projection can be ignored so far as maps of small quadrangles are concerned.

*Features shown.*—The data shown (pl. 17) are essentially the same for all maps of the topographic atlas and differ only with the limitations of the different scales. They comprise cultural features, such as all buildings, routes of communication, and other works of man that are permanent in character; the boundaries of civil divisions, reservations, and grants; the lines of the public-land surveys; the elevation of bench marks and other accurately determined useful elevations; drainage features; relief features; and so far as is practicable the names of all features, cultural and natural. Further descriptions of the three principal classes of features shown on topographic maps are given on pages 229, 242, and 245.

*Relief expression.*—For the cartographic representation of land forms several systems are available, but that which has proved most useful and has become the standard in Geological Survey work is the system of contour lines. The superiority of this system lies in the fact that not only is the vertical interval between the lines capable of being regulated to suit the character of the relief, but each contour, being a line of constant elevation, is projected upon the plane of the map with a minimum of distortion. It appears for all practical purposes with its true length and true deflections and consequently represents with exactness the contour of the ground at a given level.

A contour line may be variously defined as representing (a) an imaginary line on the ground every point of which is at the same height above sea level; (b) a level or grade line; (c) a line of constant elevation; (d) a coast line or other shore line of level water; (e) an

assumed shore line resulting from assumed rising of a body of level water.

*Contour interval.*—Standard contour intervals are 1, 5, 10, 20, 25, 50, 100, and 200 feet. Intervals of 40 and 250 feet have occasionally been used, but these intervals are not now standard. Other contour intervals may be used for special purposes, as in the international map of the world, where the contour interval is expressed in meters.

The approximate distribution of contour intervals in their relation to Geological Survey map scales is shown in the table below representing the 3,167 maps published up to June 30, 1926.

*Relation of scale to contour interval in topographic maps published by the Geological Survey up to June 30, 1926*

[Figures indicate number of maps]

Scale	Contour interval (feet)											Total
	250	200	100	50	40	25	20	10	5	1	None <sup>a</sup>	
1:250,000	29	37	12	1		1						80
1:125,000			345	252	10	25	145	1	1			779
1:62,500			24	273		107	1,230	248	33		19	1,934
1:31,250			1	2		1	5	5	268	35		302
1:24,000				5		4	4		10			23
1:21,120									13			13
1:12,000				3		4	4	2				13
Other			1	8		4	8	2				23
	29	37	383	544	10	146	1,391	258	315	35	19	3,167

<sup>a</sup> Entire area less than 5 feet above sea level.

*Colors.*—Cultural features and names are shown in black, drainage features in blue, and relief features in brown. (See pls. 18–23.) Transparent overprints of green and red are used to designate woodland areas and a road classification respectively on certain maps.

## PREPARATION FOR FIELD WORK

### INSTRUCTIONS AND PERSONNEL

Each permanent employee will receive a letter of instructions signed by the chief of the topographic division to which he is assigned and covering each assignment of field work. In the temporary absence of a division chief or in other emergencies such instructions will be signed by the chief topographic engineer. The field instructions should specify the area to be mapped and the scale and contour interval for the survey, and as a rule they should outline the general method to be employed. The personnel for the party should be stated, or authority should be given for the employment of additional assistants. The letter should also include such other instructions as may be needed. Supplemental instructions may be issued during the progress of the field work.

A topographic field party will consist of a topographic engineer (of appropriate grade) as party chief, assisted by one or more engineers, each of whom will usually have a personal assistant serving as rodman, as recorder, or in some similar capacity. In country of certain types each engineer will have two rodmen and in addition a recorder and sometimes an umbrella man. Where appropriate, axmen, boatmen, and laborers are employed. Necessary camp hands are included in the personnel.

The instructions given below are for the guidance of party chiefs preparing their own field sheets and assembling their own field material prior to taking the field. Party chiefs are urged to be methodical and thoughtful in their field preparations and to foresee the season's needs so far as practicable. If the field sheets are prepared in the Washington or other headquarters office for shipment to a party chief in the field, similar care and judgment should be used in preparation, and the interests of the field party should be fully kept in mind.

#### PREPARATION FOR NEW TOPOGRAPHIC SURVEYS

Before starting for the field the topographer should prepare his field sheets in the form best suited to the conditions under which his work is to be carried on. He should make all necessary requisitions for instruments and field supplies and should by inquiry and search collect all available data that may prove helpful during the field season.

##### PLANE-TABLE PAPER

All topographic maps made by the Geological Survey are plotted on a plane-table sheet that is mounted on a plane table. The plane-table sheet consists of two sheets of drawing paper that have been specially prepared and mounted on both sides of a sheet of cloth, with the grain of the paper on one side at right angles to the grain of that on the other side. When such a double-mounted sheet is well seasoned it will hold its shape and will withstand the ordinary effects of weather conditions that are likely to be encountered in field work. The recent experimental use of drawing paper mounted on thin metal sheets indicates that by this device the distortion of the paper due to changes in atmospheric conditions is reduced to a minimum.

#### CONSTRUCTION OF PROJECTIONS

##### GENERAL FEATURES

Polyconic projections may be constructed by hand, using the instructions and tables published in United States Coast and Geodetic Survey Special Publication 5, which gives the required values in meters on the surface of the spheroid, or using the instructions and

tables published in United States Geological Survey Bulletin 650, which gives the measurements in inches on the map scale desired; or they may be constructed mechanically by means of a Bumstead projection plate. (See p. 175.) The practice of the Geological Survey indicates preference in the reverse order from that given above, but the theory is best explained by describing the methods in the order given. In general a central meridian is assumed upon which the intersections of the parallels are plotted to scale. Each parallel is then drawn separately as an arc of a circle with its center lying in the extension of the central meridian. The arcs of the parallels are subdivided to scale, and the meridians are drawn through the subdivisions. However, in actual practice on projections of small quadrangles, the parallels are not drawn as arcs of circles, but their intersections with the meridians are plotted from the computed  $x$  and  $y$  values, and the sections of the parallels between adjacent meridians are drawn as straight lines. In polyconic projections of quadrangles of  $1^\circ$  or smaller meridians may be drawn as straight lines, and in large-scale projections of small quadrangles in low latitudes both meridians and parallels may be drawn as straight lines. For example, the curvature of the parallels of a projection of a  $15'$  quadrangle on a scale of  $1:48,000$  in latitudes from  $0^\circ$  to  $30^\circ$  is so small that it can not be plotted, and for a  $7\frac{1}{2}'$  quadrangle on a scale of  $1:31,680$  or larger the curvature can not be plotted in any latitude.

The meridional distances given in the tables apply to the central meridian of the projection, but for any standard quadrangle the differences in the curvature of the several parallels are so slight that the distances given for the central meridian can be taken for all other meridians.

Whichever method of construction is used, each projection must be subjected to a thorough test by some person other than the one who did the plotting. It is not sufficient merely to check the plottings with the figures first used. A true check consists of independent computations and measurements throughout. The verifier should therefore enter the tables anew, replot the coordinates, and, as a final test, measure the over-all dimensions of the projection and compare the lengths of its diagonals.

For identification, the latitude and longitude must be clearly marked in pencil at each of the four corners of the projection.

#### COAST AND GEODETIC SURVEY METHOD

For making a polyconic projection by the Coast and Geodetic Survey method the following materials are required: A metal straight-edge graduated in centimeters with one centimeter at one end subdivided into tenths of a millimeter, the scale being standardized and the straightedge being as long as the longest dimension of the pro-



jection; a good rigid-beam compass with micrometer movement; a hard chisel-point pencil; a plotting needle; and Coast Survey Special Publication 5. As an example the construction of a polyconic projection on a scale of 1 : 250,000 of the degree quadrangle lying between latitudes  $40^{\circ}$  and  $41^{\circ}$  north and longitudes  $88^{\circ}$  and  $89^{\circ}$  west is described.

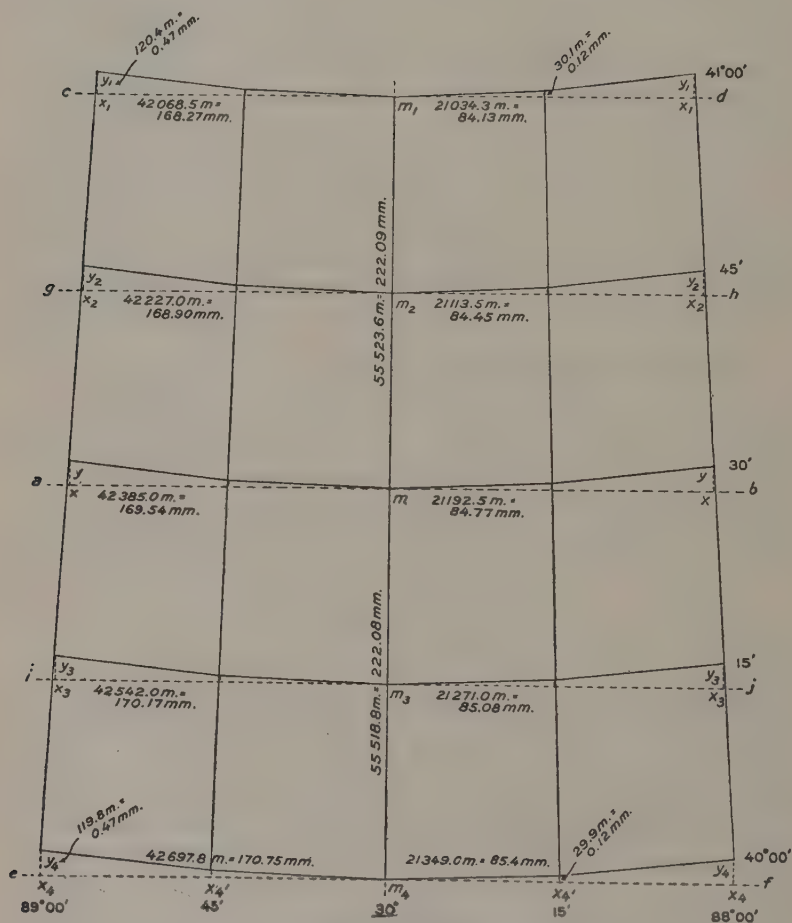


FIGURE 4.—Diagram illustrating  $1^{\circ}$  polyconic projection

Draw the central meridian  $m_1m_4$  (see fig. 4), and at the middle point  $m$  draw the construction line  $ab$  perpendicular to the central meridian. As the accuracy of the entire projection depends largely on this operation, it is advisable to swing several arcs as a check on one another. From the point  $m$  lay off the latitude intervals  $mm_1$  and  $mm_4$ , taking the distances from the table of meridional arcs. (See p. 91, Spec. Pub. 5.) The value of  $mm_1$  (the arc of the meridian between latitudes  $40^{\circ} 30'$  and  $41^{\circ} 00'$ ) is found to be 111,042.4 —

$55,518.8 = 55,523.6$  meters. Likewise the value of  $mm_4$  is  $55,518.8 - 0 = 55,518.8$  meters.

These values represent meters on the spheroid, and to reduce them to the scale of the projection it is necessary to multiply them by the representative fraction  $\frac{1}{250000}$ . The length of the arc  $mm_1$  in meters on the map is found to be 0.22209 meter, or 222.09 millimeters. Likewise the length of the arc  $mm_4$  is found to be 222.08 millimeters. It is therefore evident that for a map of this size on this scale it would have been as well to use the value in meters opposite the argument "30 minutes" from the column "continuous sums of minutes from latitude 40 degrees" for both of these values, as it is impossible to plot 0.01 millimeter. (In preparing to construct a projection it is always best to make a small sketch and set down all the measurements before beginning actual construction. Fig. 4 serves as such a sketch.) The values of  $m_1m_2$  and  $m_2m$  are each found to be 111.04 millimeters (by computation from the table or by taking one-half of the value of  $mm_1$ ), and of course the values of  $mm_3$  and  $m_3m_4$  are practically the same. The plotting should be checked by testing the length of the degree arc  $m_1m_4$ , which should be 444.17 millimeters.

At the points  $m_1$ ,  $m_2$ ,  $m_3$ , and  $m_4$  draw the construction lines  $cd$ ,  $gh$ ,  $ij$ , and  $ef$  parallel to the line  $ab$  and perpendicular to the central meridian. These construction lines must be absolutely parallel to each other and all perpendicular to the central meridian. The best results can be obtained by striking arcs from points near the extremities of the line  $ab$ , using the same settings of the beam compass that were used in laying off the distances  $mm_1$ ,  $mm_4$ , etc., and then drawing the lines  $cm_1d$ ,  $em_4f$ , etc., through the proper points on the central meridian and tangent to the proper arcs.

On each one of the construction lines lay off from the central meridian the proper abscissae of the developed parallel, selecting from the table "Coordinates of curvature" the value of  $x$  opposite the proper longitude interval and taking care to interpolate for the desired latitudes not given in the table. As this table for coordinates of curvature is computed for latitude  $40^\circ 00'$ , and the values of  $x$  change appreciably between  $40^\circ$  and  $41^\circ$ , the values taken directly from the table can be used only for  $m_4x_4$  on the line  $ef$ . The value  $m_1x_1$  should be taken from the table on page 93 of Special Publication 5 and values for  $m_2x_2$ , and  $m_3x_3$  should be interpolated between the values given in these two tables. Or these three values can be taken from the table of "Arcs of the parallel in meters" on page 90, by multiplying by 6 the value of  $5'$  of longitude given for the proper latitude. For example, on the line  $ef$  the interval  $m_4x_4$  corresponds to 30 minutes of longitude and the  $x$  value is found to be 42,697.8 meters, which is 170.75 millimeters on the map.

At the point  $x_4$  erect a perpendicular representing the ordinate of the developed parallel, selecting from the table "Coordinates of curvature" the value of  $y$  opposite the proper longitude interval. No interpolation is necessary, as the values of  $y$  change so slowly for differences of latitude that the values given in the table may be considered the average for the latitude interval from  $40^\circ$  to  $41^\circ$ . The value of  $y_4$  is found to be 119.8 meters, or 0.47 millimeter on the map. The two points thus constructed (to the left and right of the central meridian) are the lower corners of the projection. It remains to construct the two points at  $x_4$ . The  $x$  coordinate for  $15'$  of longitude is found to be 21,349.0 meters, or 85.4 millimeters on the map, and the  $y$  coordinate is 29.9 meters, or 0.12 millimeter on the map. This  $y$  value is so small that it can scarcely be plotted, and the two plotted positions of  $x_4$  may be taken as the proper position of the intersection of the 15-minute meridians with the parallel of  $40^\circ 00'$ . In theory this parallel is curved, but as the curvature can not be drawn on a map of a small quadrangle, straight lines are drawn joining all the plotted positions on this parallel. Similarly all the other parallels are developed, and the meridians are drawn through the plotted points. It will be discovered that these points fall exactly on a straight line for each meridian, and the meridians are therefore drawn as straight lines.

To test the construction of the projection set the beam compass to the diagonal distance from the lower right to the upper left corner of the projection and then check the measurement from the lower left to the upper right corner, which should be the same. Continue these diagonal tests in various combinations of small projection blocks equidistant from the central meridian, so as to check the plotting of every point. Add the proper figures showing latitude and longitude, as shown in Figure 4, and the job is completed.

The Coast and Geodetic Survey employs metal plotting scales giving the values in meters on the spheroid directly in terms of millimeters on the map for each of the map scales used.

#### GEOLOGICAL SURVEY METHOD

For making a polyconic projection by the Geological Survey method the following materials are required: A metal straightedge graduated in inches with one inch at one end subdivided into hundredths of an inch, the scale being standardized and the straightedge being as long as the longest dimension of the projection; a good rigid-beam compass with micrometer movement; a hard chisel-point pencil; a plotting needle; and Geological Survey Bulletin 650.

To illustrate this method the construction of a polyconic projection on a scale of 1:48,000 of the  $15'$  quadrangle lying between latitudes  $40^\circ 15'$  and  $40^\circ 30'$  north and longitudes  $88^\circ 00'$  and  $88^\circ$

15' west is described. (See fig. 5.) The projection will show each 5' meridian and parallel. The central meridian of the projection will represent the meridian of longitude  $88^{\circ} 07\frac{1}{2}'$  and will be used for construction only. Likewise the perpendicular crossing the central meridian at latitude  $40^{\circ} 22\frac{1}{2}'$  will be used for construction only. The geometry of the construction given below is slightly different from that given in the preceding example, owing principally to an

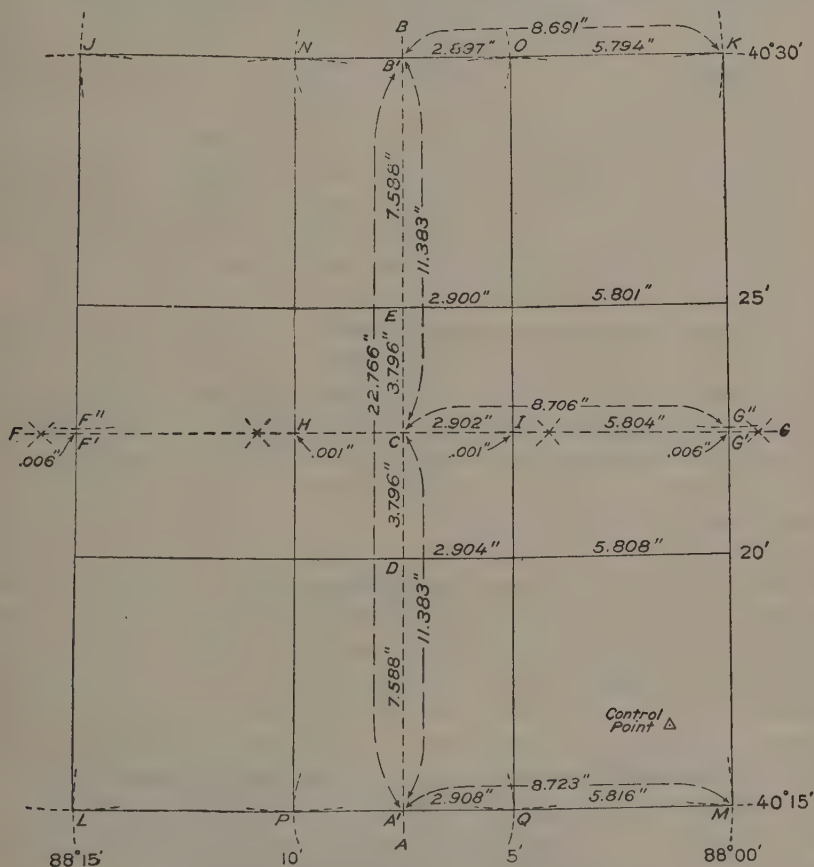


FIGURE 5.—Diagram illustrating 15' polyconic projection

effort to eliminate the plotting of the small ordinates of curvature, a task so difficult to perform in the projection of a small quadrangle.

In Table 10 on page 81 of Bulletin 650 the upper group of ordinates and meridional distances are computed for latitude  $40^{\circ}$  and may safely be used for latitudes between  $39^{\circ} 30'$  and  $40^{\circ} 30'$  without interpolation between the values given therein and those given in the second group, which are computed for latitude  $41^{\circ} 00'$ . By interpolating in the upper group so far as necessary the meridional distance



for  $2\frac{1}{2}'$  of latitude is found to be 3.796 inches, for  $5'$  7.588 inches, for  $7\frac{1}{2}'$  11.383 inches, for  $10'$  15.178 inches, and for  $15'$  22.766 inches. (New tables are being computed in which the meridional distances, ordinates, and abscissas are given without interpolation for all the latitude and longitude intervals needed in the construction of a projection of a standard quadrangle.)

In the part of the table headed "Abscissas of developed parallel" the  $x$  values for  $2\frac{1}{2}'$  and  $7\frac{1}{2}'$  of longitude in latitude  $40^\circ 15'$  are found to be 2.908 inches and 8.723 inches, respectively. The  $x$  values for latitudes  $40^\circ 20'$ ,  $40^\circ 22\frac{1}{2}'$ ,  $40^\circ 25'$ , and  $40^\circ 30'$  are shown in Figure 5.

In the upper group of "Ordinates of developed parallel" the  $y$  value for  $7\frac{1}{2}'$  of longitude is found to be 0.006 inch. The ordinate for  $2\frac{1}{2}'$  of longitude is not given, but as the ordinates vary as the square of the distance from the central meridian the  $y$  value for  $2\frac{1}{2}'$  is one-fourth of that given for  $5'$  or one-ninth of that for  $7\frac{1}{2}'$ —that is, 0.0007 inch, or approximately 0.001 inch.

These are all the measurements needed to proceed with the construction of the projection. It is impossible to plot the  $y$  value for  $2\frac{1}{2}'$  of longitude and difficult to make an individual plotting of the  $y$  value for  $7\frac{1}{2}'$  of longitude, but 0.006 can be added to or subtracted from other measurements of meridional arcs and the resultant distance measured on the metal scale, and this is done in the following description:

Draw the central construction meridian AB in vertical position near the center of the map, select the middle point C as the center of the projection, and lay off from C the meridional distances for  $2\frac{1}{2}'$  and  $7\frac{1}{2}'$  of latitude, CE (3.796 inches) and CB' (11.383 inches) above and CD (3.796 inches) and CA' (11.383 inches) below. The over-all distance A'B' (22.766 inches) for  $15'$  of latitude should be used to check the plotting. At the point C erect the perpendicular FG, using the points A' and B' as centers for long arcs and the points D and E as centers for short arcs. Lay off on the construction line FG the abscissas of the developed parallel for  $2\frac{1}{2}'$  and  $7\frac{1}{2}'$  of longitude, CH and CI (2.902 inches) and CF' and CG' (8.706 inches).

With the points F' and G' as centers and a radius equal to the meridional distance for  $7\frac{1}{2}'$  of latitude plus the ordinate for  $7\frac{1}{2}'$  of longitude ( $11.383 + 0.006 = 11.389$  inches) strike arcs at J and K. Then with the same points as centers and a radius of 11.377 inches ( $11.383 - 0.006$ ) strike arcs at L and M. In striking these arcs use the metal point of the beam compass rather than the pencil point and either scratch the paper lightly or place under the metal point a small piece of carbon paper made by rubbing a piece of thin tracing paper with a hard pencil. This obviates the inaccuracy of using the

pencil point of the beam compass to take an exact measurement from the scale.

With the points H and I as centers and a radius equal to  $7\frac{1}{2}'$  of latitude (11.383 inches) measured along the central meridian, strike arcs at N and O above P and Q below. The true meridional distance as here used should always be taken in constructing the inner meridional distance for  $7\frac{1}{2}'$  of latitude on a scale of 1:48,000, or larger, as it is impracticable to use the small ordinate for  $2\frac{1}{2}'$  of longitude. However, should the more rigid construction be required, it may be done in the following manner: With points H and I as centers and a radius equal to  $7\frac{1}{2}'$  of latitude measured along the central meridian plus the ordinate for  $2\frac{1}{2}'$  of longitude ( $11.383 + 0.001 = 11.384$  inches) strike arcs at N and O. Then with the same points as centers and a radius equal to the meridional distance minus the  $2\frac{1}{2}'$  ordinate ( $11.383 - 0.001 = 11.382$  inches) strike arcs at P and Q.

With the points B' and A' as centers and radii equal to the proper abscissas, strike arcs at J, K, L, M, N, O, P, and Q. Check the length of the diagonals JM and KL, which should be exactly the same. Draw the straight lines JL and KM through the intersections of the arcs at J, L, K, and M. These lines represent the limiting meridians on the projection. Draw the straight lines NP and OQ through the intersections of the arcs at N, P, O, and Q. These lines represent the two inner meridians on the projection, and the four intersections at the top and the four at the bottom of the projection are the exact intersections of the four meridians with the limiting parallels.

With the beam compass set at the length of the meridional arc for 5' of latitude, plot along all four meridians down from J, N, O, and K and up from L, P, Q, and M, and check the middle 5' sections of the meridians, thus locating the intersections of the four meridians with the parallels  $40^{\circ} 20'$  and  $40^{\circ} 25'$ .

All the necessary intersections for the projection of this 15' quadrangle have now been plotted without trying to make an individual plotting of 0.006 inch from the points F' and G', which only the most skilled draftsmen can accomplish, and the same setting of the beam compass has been used for all equal measurements, thereby strengthening the construction. Check the construction by measuring over-all distances and by testing corresponding diagonals of all combinations of projection blocks.

Although it is customary to show only the 5' intervals on a projection for a 15' quadrangle, it may be desired to develop the central parallel, which, in the projection under construction, would fall on latitude  $40^{\circ} 22\frac{1}{2}'$ . With the beam compass set at the meridional distance for  $7\frac{1}{2}'$  and plotting along the meridians down from J and K and checking by plotting up from L and M locate the points F'' and G'', which are the intersections of the limiting meridians with

the central parallel at latitude  $40^{\circ} 22\frac{1}{2}'$ . The points H and I already determined are the intersections of this parallel with the inner meridians, as no ordinates can be plotted at these intersections.

Draw the parallels as straight lines between the plotted intersections. This practice is permissible as the curvature of the parallels of any standard quadrangle within the limits of the United States is too small to be drawn as a curve. Insert the figures for latitude and longitude as shown in Figure 5, and add the scale, the name of the quadrangle, and the initials or name of the person making the construction. The projection is then completed, but it should be checked carefully by another person.

In any projection where the ordinate of a developed parallel at the limiting meridians is less than 0.005 inch it is impracticable to plot the curvature, and the parallels should be represented as straight lines perpendicular to the central meridian. This will be true of projections of maps of standard quadrangles on the scale of 1:48,000 between latitudes  $0^{\circ}$  and  $30^{\circ}$  and on scales of 1:31,680 and larger in any latitude.

Bulletin 650 does not give projection tables for all the map scales that are used by the Geological Survey. For example, tables are given for the scale of 1:48,000, which is the field scale for maps published on the scale of 1:62,500, but no tables are given for the scale of 1:96,000, which is the field scale for maps published on the scale of 1:125,000. New tables are being prepared to cover all the scales used in standard mapping and all latitudes from  $0^{\circ}$  to  $50^{\circ}$ , but until these are available and within certain limitations a particular projection table can be used for a scale half as large or twice as large. The abscissas of developed parallels and the meridional distances are both practically in direct proportion to the scales, so that the abscissa for  $2\frac{1}{2}'$  of longitude at latitude  $40^{\circ}$  on the scale of 1:48,000 is the same for  $5'$  of longitude at latitude  $40^{\circ}$  on the scale of 1:96,000. Likewise the meridional distance given for a latitude interval of  $2\frac{1}{2}'$  on the scale of 1:48,000 is the same for  $5'$  on the scale of 1:96,000.

The ordinates of developed parallels are also directly proportional to the scales, but the ordinates are also proportional to the squares of the distances from the central meridian, and this may lead to confusion in interpolation for a different scale. For example, the ordinate of developed parallel for a longitude interval of  $5'$  in latitude  $40^{\circ}$  on a scale of 1:48,000 is 0.003 inch. The ordinate is not the same for a longitude interval of  $10'$  on a scale of 1:96,000, but is 0.006, or twice as much.

The following rules may disclose discrepancies in the third decimal place, but these discrepancies will be too small to plot: To double the scale—for example, to make a projection on a scale of 1:24,000 from tables for the scale of 1:48,000—use correct arguments for the



scale desired and multiply all values given in the table by 2. To halve the scale—for example, to make a projection on a scale of 1:96,000 from tables for the scale of 1:48,000—use correct arguments for the scale desired and divide all values given in the table by 2.

#### USE OF BUMSTEAD PROJECTION PLATE

Projections for 15' quadrangles on a scale of 1:48,000 may be made without the use of projection tables by means of the Bumstead projection plate (pl. 8), which consists of a heavy metal plate 29 inches long and 25 inches wide, smooth on the under surface and carrying on the upper surface 20 graduated scales, 16 of which, arranged in rows of four each, are placed in such positions as will give the 5' latitude and longitude intersections of a 15' quadrangle when the index line of a small separate key plate is successively placed opposite the appropriate lines on the 16 latitude scales. The other four scales give the intersections of a straight line joining the middle points of the limiting meridians of the quadrangle with the four 5' meridians of the projection, so that the projection can be constructed in two half sheets. For all practical purposes on large-scale projections this straight line can be considered the middle parallel. Each scale is graduated for ranges in latitude from 25° to 50°. As the longitude interval will be the same for all 15' quadrangles in the same latitude, only latitude figures are given on the plate. Each degree of the four scales marking the four corners of the projection and each degree of the two intermediate outer scales on both sides (eight in all) is divided into quarters of a degree (15' spaces), and each degree of the eight inside scales is divided into half degrees (30' spaces). The other four scales (middle latitude) are divided into quarters of a degree on the two outer scales and half degrees on the two inside scales.

Example: To construct a 15' projection for a quadrangle between parallels 40° 00' and 40° 15' and meridians 90° 00' and 90° 15', weight the plate on the paper sufficiently to avoid slipping. Place the index line of the separate key plate (pl. 8, *B*) opposite latitude 40° 00' on each of the four scales on the lower margin of the plate; and at each 40° 00' setting run a needle down the triangular channel of the key and through a slit in the plate and the needle points in the paper will mark the southwest corner, the southeast corner and the two 5' intersections on the south edge of the projection. Similarly place the index line of the key successively opposite latitude 40° 05' on each of the four scales next north by interpolation of thirds on the two outer scales and by interpolation of sixths on the two inner scales, and at each setting make a needle point on the paper as before. On the four scales next north make the settings at latitude 40° 10', and on the last or upper row of four scales at latitude 40° 15'; on the upper line the points marked will be the northwest corner, the north-



east corner, and the two 5' intersections on the north edge of the projection. These 16 plottings give all the 5' intersections of latitude and longitude for a 15' quadrangle. If a middle latitude line is desired, or if the projection is to be made in halves, plot the  $40^{\circ} 07' 30''$  intersections at the four scales across the middle of the plate.

A projection that is made as described above will correctly show a slight curvature of the parallels.

Projections for  $7\frac{1}{2}'$  and 30' quadrangles on scales of 1:24,000 and 1:96,000 respectively may also be made by means of the Bumstead projector, by assuming that the 16 scale settings give  $2\frac{1}{2}'$  and 10' intersections respectively. Theoretically this is not true, for although the abscissa of a parallel on the ground—the  $x$  value—is directly proportional to the distance from the central meridian and therefore the representation of half or twice its abscissa on projections half or double the scale of the projection plate will be the same as for the unit length on the scale of the projection plate, nevertheless the ordinate of the parallel—the  $y$  value—varies as the square of the distance from the central meridian. Therefore use of a projection plate made for the scale of 1:48,000 will theoretically result in plotting too much curvature in the parallels on a scale of 1:24,000 and too little on a scale of 1:96,000. For all practical purposes in latitudes below  $50^{\circ}$  this discrepancy may be neglected for a 1:24,000 projection, in which the parallels should be drawn as straight lines connecting the outer needle points, for the reason that no curvature can be shown on that scale within the limits of a  $7\frac{1}{2}'$  projection. For a 1:96,000 projection the parallels may be drawn through the upper side of the dots at the outer needle points and then through the lower side of the dots representing the inner intersections of the same parallel, as here the curvature is still small and not otherwise readily plottable.

#### CONVERGENCE OF MERIDIANS

The convergence of the meridians can not be appreciably plotted within the limits of standard quadrangle maps in latitudes below  $50^{\circ}$  that are drawn on a scale of 1:31,680 or on any larger scale. On a scale of 1:62,500 (or on the corresponding field scale of 1:48,000) the convergence is just plottable within the limits of a 15' projection representing a quadrangle in southern Florida or Texas, but the convergence is increasingly appreciable as the latitude increases. No convergence can be shown on maps of 15' quadrangles in Hawaii. On maps representing 30' and  $1^{\circ}$  quadrangles that are published on scales of 1:125,000 and 1:250,000, respectively, the convergence is considerably larger, for the reason that the eastern and western limits of the quadrangle are at greater distances from the central meridian.

The amount of the convergence, if any, is shown on published maps at the two northern corners of the projection (pl. 15), where it is represented by the spaces between the meridians and the neat lines, the latter being drawn parallel to the central meridian of the map. Neat lines are not to be drawn on field projections.

#### CONTROL DATA

All the horizontal and vertical control data that are available for any quadrangle will be furnished by the chief of the section of computing on requisition, which should be submitted in duplicate. The section of computing will return one copy of the requisition containing a sketch showing the approximate position of all triangulation, transit-traverse, and level lines that fall within the area to be mapped and the necessary descriptions for these triangulation, traverse, and level positions. Data thus supplied will be carefully examined and should be returned intact with the field sheets when the sheets are forwarded to the office.

#### PLOTTING HORIZONTAL CONTROL

A triangulation or transit-traverse control point may be plotted by computing the proportional parts of the arcs of the limiting meridians and parallels of the small projection block in which the point falls that conform to the latitude and longitude of the point. For example, it is desired to plot on a projection on the scale of 1:48,000 the position of a point whose latitude is  $40^{\circ} 16' 35''.75$  and longitude is  $88^{\circ} 01' 27''.55$ . This point will fall in the lower right-hand 5' block of the projection illustrated in Figure 5. The sides of this projection block represent parallels  $40^{\circ} 15'$  and  $40^{\circ} 20'$  and meridians  $88^{\circ} 00'$  and  $88^{\circ} 05'$ , and the block covers 300 seconds of latitude and longitude. The 5' arc of parallel  $40^{\circ} 15'$  is represented by a length of 5.816 inches and that of parallel  $40^{\circ} 20'$  by a length of 5.808 inches. The 5' arc of each limiting meridian is represented by a length of 7.588 inches. The point falls  $1'35''.75 = 95''.75$  above the parallel  $40^{\circ} 15'$ . The proper distance to be plotted along the limiting meridians above the line on the projection representing this parallel is given by the proportion  $95.75:300 :: y:7.588$  inches, and  $y$  is found to be 2.242 inches. Similarly the proper proportional parts of the two limiting parallels to the left of the intersections with the meridian  $88^{\circ} 00'$  are found by the following proportions: For latitude  $40^{\circ} 15'$ ,  $87.55:300 :: x:5.816$ , from which  $x$  is found to be 1.697 inches; for latitude  $40^{\circ} 20'$ ,  $87.55:300 :: x':5.808$ , from which  $x'$  is found to be 1.695 inches. These values should be plotted on the proper meridians and parallels, and the intersection of the two lines joining corresponding latitude and longitude positions on the

limiting meridians and parallels will be the location of the control point.

The method described above is laborious, and the plotting of control points is facilitated by use of latitude and longitude plotting scales so subdivided that the proper readings in minutes and seconds may be plotted without computation. The plotting scales are available for all standard projection scales and are made slightly longer than the corresponding dimensions of the individual projection blocks in the lowest latitude for which their use is intended. The scales are used diagonally between the limiting parallels and meridians, and thus the same plotting scale can be used for a wide range of latitude. At least two plottings of both latitude and longitude positions are so made as to embrace the position of the point, and the intersection of the lines joining the corresponding plottings will be the position of the point. The plotting scale for 1:48,000 is shown in Plate 9, A.

#### MAP BORDERS

It is of prime importance that contiguous topographic maps shall join perfectly, so that when they are laid edge to edge the lines on them shall pass without break or offset from one to the next. For this purpose the engineer, before beginning field work on a new quadrangle, should procure photographs, photolithographs, or tracings of adjoining edges of all previous maps (including woodland) that are on the same or larger scales. Data that are on a different scale from the new field work should be reduced to that scale by photography. The strips so furnished should be preserved as a part of the field material and returned for the office files. The data on the strips should be transferred to the field sheets. (See "Map borders," p. 227.)

#### DATA FROM OTHER SURVEYS

*Source of material.*—Existing map material of Federal, State, and municipal surveys and other authenticated organizations should be diligently sought, both before leaving the office and after reaching the field. The files of the map information office of the Federal Board of Surveys and Maps (Interior Department Building) should be consulted freely.

Maps of the General Land Office (see p. 179), the Coast and Geodetic Survey, the Hydrographic Office of the Navy, the Corps of Engineers of the Army, the Mississippi River Commission, the survey of the Great Lakes, the national boundary surveys, State boundary surveys, boundaries of national parks, forests, monuments, game and bird preserves, Indian and military reservations, land grants, surveys made by the Bureau of Reclamation, Forest Service, and Bureau of Soils should be obtained, and such of them as prove,



on field examination, to be adequate, should be incorporated in the field sheets, with proper recognition. (See "Credit for outside data," p. 307.) All such material will, upon requisition, be reduced by photography to the field scale.

*Land Office data.*—Before reaching the field party chiefs must provide themselves with copies of the latest plats of the public-land surveys, if any, of the assigned areas, and if practicable these plats should be reduced to the scale of mapping. It is important that the data furnished should be the latest available and that they should include any resurveys or retracements and any exterior notes of townships not yet sectionized that fall within the limits of the quadrangle to be surveyed. Inquiry should also be made to ascertain whether any of the plats are under suspension by the General Land Office.

Before starting work in national forests topographers should check off on forest maps the Land Office corners that have been found by the Forest Service and also corners that have been looked for and not found; such information is on file at the headquarters of each supervisor and also at each district office. Inquiry may also often be advantageously made of county surveyors, deputy mineral surveyors, and local engineers as to the existence and location of known corners or ties.

*Other reference data.*—The following additional maps and data should be assembled for field use: Post-route and rural-delivery maps; Geological Survey index circular, corrected to date, together with copies of engraved maps or advance sheets of all maps of areas adjoining the proposed new quadrangle; list of incorporated places given in Census reports; alinement maps of railroad valuation surveys; 1:500,000 scale State map; State highway and other route maps.

#### ENDING OFFICE SEASON

At the end of the office season turn in to the section of inspection and editing all map material pertaining to the office season that is not needed for field work. Clear desk and map file cases. Turn in to the division of field equipment all office instruments not needed in the field. Submit office report.

### PREPARATION FOR REVISION OF TOPOGRAPHIC MAPS

#### FIELD SHEETS

The field revision of a topographic map will be made upon a reproduction of the latest print of the map, printed for the purpose on double-mounted drawing paper. The field sheets for revision are printed in relatively weak colors, often referred to as nonphotographic, in order that the revision corrections, where inked in the standard



strong colors, may be reproduced photographically and thus furnish copy for transfers to the plates which are afterward to be corrected. Such field sheets may be prepared under one of the three plans described below:

1. A printed copy of the map may be reproduced by photolithography, enlarged to the usual field scale, and printed in faint blue, which is only weakly photographic. This process should not be used, however, where distortion of the paper on which the map has been printed has so changed the map projection that its dimensions are long or short in one direction and not proportionately so in the other direction. The projections of maps selected as camera copy for reproduction by this method should be carefully tested before use.

2. Transfers to stone may be made from the three copper plates on which the map was engraved and a special print of the map made in three different weak colors, such as faint blue for culture, light gray for drainage, and light pink for contours, each printing being as carefully registered as for a map printed in the usual way. Such a revision field sheet has the advantage of true scale and of the same use of distinctive colors for the three principal classes of features as is shown on a printed map; but the advantage of the usual field scale is lacking. Plotting scales are provided graduated to both miles and feet on the usual publication scales.

3. The process described in paragraph 2 may be varied to provide for enlargement to field scale before transferring to the printing stones. Revision sheets prepared by this process combine all the advantages of the other two; that is, they are on true scale, are on the field scale, and are printed in three distinctive colors.

The first process described above is the cheapest of the three, and the third is the most expensive. The selection will be based on field and office conditions, the nature of the country represented, and the usual relation between field and publication scales.

#### CONTROL DATA

A complete set of control notes, both horizontal and vertical, must be obtained before starting field revision. The control data should be requested from the section of computing on a form provided for the purpose.

#### OTHER REVISION DATA

So much of the material described under "Data from other surveys" (p. 178) as will apply to the revision work that is to be undertaken should be assembled. Of especial importance are post-route map, Land Office data, reservation maps (national forest, etc.), index circular, and maps of adjoining quadrangles.

## FIELD WORK

## STANDARDS FOR FIELD WORK

## ACCURACY

*Accuracy defined.*—A topographic map, irrespective of scale, is accurate if it is based upon a sufficient amount of well-distributed and well-adjusted control, to which the carefully considered topographic features appropriate to that scale have been tied with a maximum of refinement in field measurement and in plotting. (See "Definition of a topographic map," p. 161.)

Accuracy in a topographic map can be truly measured only by a combined appraisal of the character and amount of its control, its adjustment, the accuracy with which the field measurements have been taken and plotted, the ease with which the features mapped can be identified, its amount of detail or degree of generalization, the consistency of its parts, its freedom from errors and omissions, and its date of survey.

*Control factor in map accuracy.*—The control that is necessary for accuracy in a map embraces first the primary control—of first, second, or third order—both horizontal and vertical, upon which the survey for the map must rest. Of this control but a relatively small amount is needed, for the reason that initial control is expanded and supplemented by further topographic control of another kind, obtained by means of the topographic mapping operations themselves, such as plane-table traverse and plane-table triangulation, as a result of which the area under survey is so gridironed or covered by lines and locations that no essential map feature is so far from a traversed line or located point that it can not be satisfactorily seen and delineated.

Careful judgment will be required to cover the entire quadrangle adequately to the end that no part of the area be mapped that is not properly seen and that too much control and time be not devoted to portions of the area that happen to be easy of access and too little given to other portions that happen to be difficult of access.

*Accuracy of adjustment.*—If a map is in accurate adjustment then all its parts are in correct relative position. This important and desirable quality in topographic maps is insured through the use of control and by means of adjustment. The initial primary control for a map is so tested by the geodetic engineer that it may be accepted as accurate by the topographic engineer, but its plotting on the field sheets must be checked before it is used. Inasmuch as all single observations, such as the measurement of a distance or an angle or the determination of an elevation, are inherently subject to error, however slight, and as continuous lines are subject to errors of accu-

mulation, both in distance and in direction, such map measurements and observations must be adjusted in order to distribute the small unavoidable errors in such a way that they may be eliminated or made negligible.

An area may therefore be adequately covered by supplementary control and be thoroughly mapped so far as map features go, and yet the map may be out of position locally through the presence of accumulated errors of survey that remain unadjusted. A common source of unadjusted error is the use of unchecked lines of plane-table traverse that may contain unsuspected errors and thus result in the false location on the map of the area affected by the errors; and inasmuch as errors in unchecked lines often result in the forcing of other features into a remaining space on the map paper, topographers are cautioned to run spur lines with the utmost care. Another example of possible error through unchecked spur lines appears when each of the opposite sides of a ridge or mountain is mapped from a traverse line that has been run without closure and where the effect of the error on one or both sides of the ridge remains undetected through lack of intervisibility. Obviously large errors are not subject to adjustment and must be located and corrected, and if they can not be located that part of the survey must be rerun or remapped. (See "Errors and omissions," p. 185.)

*Accuracy of observations and of plotting.*—As it is a waste of effort and expense to execute surveys on the ground with an accuracy greater than can be plotted on the scale of the field sheets, and as it is a failure to get full value from effort and expense already incurred to plot the results of field work with an accuracy less than that of the observations themselves, the topographic engineer should think of ground features in terms of scaled map distances and dimensions and then correctly plot his measurements under all the favorable plotting conditions, such as light, magnification, needle point, and the avoidance of parallax. Refinement in paper accuracy is therefore quite as important as care in field measurements.

*Identification of features.*—One of the simplest tests of the accuracy of a topographic map is to examine it in the field and note the relative ease or certainty with which the features represented on the map may be identified on the ground or the ease with which features seen on the ground may be recognized on the map. In the hands of a trained map reader such a test is one of the most severe to which a map may be subjected, and for this reason it is the preliminary basis for a Geological Survey field inspection of topographic mapping, either in progress or completed. Inasmuch, however, as the topographic engineer sees more on the ground than he can plot on his map, so will the field inspector observe more on the ground than he can find on the map; and inasmuch as the map maker must



learn to abstract what he sees, so must the inspector or the map reader learn to read the abstract.

If the features shown on the map and the features seen on the ground are thus readily recognized and if several corresponding features appear to be in the same relative position, each to the others, the map may be regarded as accurate in the degree that the map user is himself versed in maps and their interpretation. Correct interpretation of a map is therefore a factor in its best use. To interpret a map it is necessary first to visualize its scale and contour interval and become very familiar with them and with their possibilities and limitations. Familiarity with the scale of a map may be acquired in several ways—for example, by identifying points in common on the ground and on the map; by orienting the map by means of the points thus identified and sighting others for additional identification; where the identification of a first point is uncertain, by orienting the map by needle, allowing for magnetic declination; by measuring a distance on the ground and plotting the corresponding distance on the map; or by traveling a road or other recognizable route and comparing ground and map appearances, checking on recognized points or places. The mistaken identification of a map feature is a common source of discouragement to a map user and will tend to increase his perplexity until he locates himself. A map that is found to be accurate by an expert critic will obviously be found accurate by map users who are less critical and less observant, but the reverse is not necessarily true.

*Detail and generalization.*—In measuring the accuracy of a map by the faithfulness with which ground detail has been represented on it or appraising it by the success that has been attained in the generalization of such detail as is beyond the scale of the map, it is necessary to understand the uses and the meaning of the terms “detail” and “generalization” and their application to Geological Survey maps. These terms describe two relative conditions that are opposite or complementary. “Detail” implies a refined treatment and suggests literal mapping; “generalization” signifies a broad treatment and involves an abridgment. The use of the terms may be further defined by an example. A map drawn on a scale of 1:24,000 should represent a region in detail as compared with a map of the same region drawn on a scale of 1:48,000, on which the representation must be confined to a broad generalization of the same features.

“Detail” may refer to a ground topography that is intricate as well as to its refined representation on a map, but “generalization” distinctly refers to a process. When referring to the country rather than to a map we may speak of detailed topography but not of generalized topography. When we speak of generalized topography



on a map we mean that abridged, condensed, or abstracted treatment of a detailed ground topography that is made necessary by the limitations of scale, contour interval, and expediency. Ground detail may range in degree or amount from the excessive detail of city culture and bad-land relief to the relatively negligible detail of smooth broad or coastal plains.

Inasmuch as the published topographic maps of the Geological Survey represent greatly reduced abstracts of nature, the topographic engineer must determine what proportion of the ground detail can be adequately shown on the scale of publication. The smaller the publication scale and the more intricate the ground detail the more complicated is his problem; the larger the publication scale and the less intricate the ground detail the larger will be the proportion of it that can be delineated and the simpler will be his task. But whatever the scale or whatever the amount of the ground detail, the resulting map must in a large degree represent a generalization, and his problem is first how much must he generalize and second how can he best do it.

Generalization can be further explained by an example: On the larger scale of 1 : 24,000 a stream may be plotted to show all its bends and all its tributaries; on the smaller scale of 1 : 48,000 the smaller bends and the shorter tributaries will be omitted. This example comprises two phases of map generalization: The smallest tributaries have been omitted because they would not show on the small scale, being only microscopic ticks or specks against the main stream; but the smaller bends in the main stream have been disregarded because they are difficult to draft on the small scale and are equally difficult to find on the map, and instead a stream line is plotted in which no attempt is made to show them. One phase of generalization involves omission; the other substitution. The contour system that is dependent on the drainage likewise becomes successively generalized as it is mapped on smaller scales. In a similar sense, a small hill may be a conspicuous feature on a detailed map of small contour interval (5 or 10 feet) and yet not be shown on a small-scale map of larger contour interval (50 or 100 feet). Generalization, then, means elimination, and the greater the generalization the more drastic must be the process.

*Consistency in accuracy.*—The map should be as consistently accurate in all its parts as is practicable. If two or more topographers are responsible for the mapping of independent areas on the same or adjoining quadrangles, they should compare their maps not only at their common borders but throughout, in order that they may reconcile any differing interpretations of the country or of the instructions under which they are working. Such comparisons should include examination of drainage, road and woodland classification,

and the names of features in common, as well as the discussion of any unusual features.

*Errors and omissions.*—The most obvious source of inaccuracy in a map is error. A map error may be caused by an erroneous measurement or erroneous plotting of a distance, by the erroneous measurement of an angle, or by an error in a field computation. A map error may also result from the misinterpretation of the shape of a distant or otherwise veiled feature seen in perspective. If an error is followed by another error that is made in the opposite direction the errors are termed compensating, in that one tends to balance the other. Where compensating errors are nearly equal the results under certain conditions, as in running a traverse line, may have a false appearance of accuracy in that the line may check out and yet be in error in two places. Small compensating errors may usually be disregarded, but where such errors are large they are a source of perplexity until found and corrected.

In order to provide against error all traverse lines so far as practicable should be run in circuits closing on themselves or run from one located point to another; and, barring compensating errors, a line that "closes" or checks is assumed to be correctly plotted. The errors to be chiefly guarded against are therefore those that may result from isolated measurements unrelated to other features and the possible accumulation of errors in unchecked lines.

The plane-table methods employed in topographic mapping enable the topographer to detect and correct most errors in the measurement of distances and most errors in plotting, because such errors usually produce erroneous mapping that will not fit other data that are correctly placed from other control. The topographer can therefore often detect errors in mapping through the appearance of the map alone, because the map is plotted in the field with the country that is being mapped directly in front of him. The check on the accuracy of the map that is thus afforded by its constant comparison with the features themselves as they are being mapped is a test that should be repeatedly applied by topographic engineers.

Inaccuracies in a map may also result from omissions. A house or a name may be omitted through inadvertence, and a spur or a tributary stream may be omitted because of lack of sufficient supplemental control. In the first case there has been lack of care, and in the second case the standard of accuracy is deficient. A feature that has been plotted in the field may be lost before it is inked because of faint penciling, or it may be lost during the inking through inadvertent erasure; and a feature that has been inked may be omitted in the engraving or inadvertently brushed off in the transfer operations prior to printing. Firm penciling, care in cleaning the sheets, and faithful proof reading are the safeguards against such omissions.

The omission of essential features from a map because they were not seen or recognized as such during the progress of the field work can be guarded against only by close observation combined with a control that is fine enough to close up all unseen gaps.

*Date of survey.*—Map accuracy must be considered in terms of the date of the survey. This date is stated on each published map, and the accuracy of the cultural representation must be considered as of that date. Although reasonable effort should be made to obtain information as to all important changes in culture, even though the area affected has been passed by in the survey operations, the policy of the Geological Survey is to plot no feature that has not been constructed on the ground and to show no proposed features. Such features as roads and railroads under construction may be plotted so far as actually graded, but unless they are known to be in use when the map is inked they should be shown on the final drawing in red, as features not to be included on the published map.

#### SPEED

Speed may be expressed in terms of elapsed time or rate of progress. For example, a quadrangle covering an area of 225 square miles may be reported as mapped in five months or at the rate of 45 square miles a month. The rate at which mapping should progress will differ more for different kinds of country than for different individuals, and in general it will differ more for different mapping scales than for different kinds of country, and to a lesser extent it will differ with different contour intervals.

Differences in speed between individuals are accounted for in part by differences in natural and developed ability and in part by different conceptions of the standards of accuracy. Speed is increased by the use of the most efficient mapping methods, through cooperation, by the advance planning of work, by experience, and by diligence. Speed is reduced by inclement weather and by errors.

*Speed through efficient methods.*—Experience justifies the use of different mapping methods for different types of country and to some extent for different scales. Although the engineer will know in advance and usually before reaching his field of work what general type of topography to expect, he can not anticipate the detailed types to be found, nor anticipate how often or abruptly these types may change within the same quadrangle. The topographic engineer should therefore have so good a working knowledge of all field mapping methods in approved Geological Survey practice that he may be ready to use those methods that are locally best suited to the varying types of country he is called upon to map. There are also many short-cut devices applicable to all methods of mapping, and topographers



are encouraged to become familiar with them through contact with others and through personal experience.

*Speed through cooperation.*—A topographic engineer seldom works alone, being usually assisted by a rodman or by a station assistant. He is frequently further assisted by traversemen, each working separately and each in turn assisted by a rodman. The map work of the traverseman is transferred and adjusted into the topographer's map and becomes a part of it. The output of the combined party is credited to the topographic engineer as party chief and is measured in terms of the number of square miles completely mapped each month. Party chiefs therefore should not overlook the possibilities of increasing the efficiency of their assistants and thereby increasing not only the accuracy but also the speed of the output of the party. Assistants acquire efficiency more rapidly through personal attention and training given to them than through unaided experience. Assistants, including junior engineers, should be fully instructed in their duties and should be kept as fully occupied as the nature of their work and their fitness for added duties justifies.

*Speed through advance planning.*—A material factor in the speed of topographic mapping is a well-considered and reasonably complete plan of work for the season, augmented by a daily and weekly laying out of work in advance. The work of engineering assistants, working separately, should be similarly outlined well in advance, in order that it may proceed without delay and that the party chief may have the prompt use of the work of his assistants when he needs it.

Planning involves the selection of areas for initial and subsequent work, selected in the most advantageous sequence in which the work can be taken up for survey and mapping; the advance assignment of tasks and areas to assistants who are working separately; and the appropriate assignment of method to country and to the available personnel in order that the relative strength of supplemental control on which to adjust the completed survey may be maintained in advance. It also provides for the availability of essential outfit when and where it is needed. Planning should include a consideration of the party personnel, as to whether it is sufficient, too small, or unnecessarily large, and if men can be spared for other work or if further assistance is needed timely notice should be given, in order that there may be the fullest adjustment to the needs of all.

*Speed through experience.*—Experience should be rated in terms of work performed as well as by length of service; and in considering work performed, its variety as well as its amount should receive consideration. At the outset of an engineer's career a part of his time will be spent in acquiring a working experience, and in order that he may build soundly his speed at this stage should be of secondary



importance, but as experience is gradually gained his rate of progress should increase. Party chiefs have in this respect a responsibility and a constructive opportunity in the proper guidance and instruction of the newer men.

The rate at which mapping experience may be acquired may obviously be increased through close observation and the application of mapping principles and also through the discussion of mapping and its problems with others. Topographers are encouraged to get together in all appropriate ways for the interchange of thought and experiences in connection with the furthering of their work.

*Speed through diligence.*—Diligence is a prerequisite for speed. Diligence, however, must first be used in attaining thoroughness and accuracy, but when these essentials have been adequately acquired further diligence should be directed toward the expedition of the work rather than toward a refinement of the mapping that would be beyond the scale of the field work. Inasmuch as topographic field work is generally done at considerable distances from any office headquarters and involves the expensive maintenance of a party in the field, topographers are expected to prosecute their work with zeal and perseverance and to try so far as possible to overcome the obstacles that will always in some measure confront them. Among such obstacles are inclement weather, short days, extremes of heat or cold, and country that is difficult of access. The Geological Survey utilizes the favorable working seasons and conditions to the fullest degree practicable, but the exigencies of the public needs frequently demand that topographic work be carried on under less favorable working conditions, and at such times the resources of the engineer should be diligently used in devising ways and means to keep the mapping in progress, even though at reduced speed.

#### LEGIBILITY

*Legibility in general.*—The relations between the legibility of a field sheet, that of an inked office drawing, and that of a printed map are so close that the need for legibility in field penciling can be best understood when it is considered in connection with the similar need for legibility in inking and in reproduction. The readability of a printed map depends upon the clearness of its reproduction, the detail of its treatment, and the ability of the map user to read it. In meeting demands for detailed maps there is always danger lest more time be spent in obtaining detailed representation in surveys, in drafting, and in reproduction than the scale of the reproduction warrants on the one hand or than the legibility of the resulting map warrants on the other hand. Less detail of treatment, however, does not imply less accuracy (see "Accuracy," p. 181), but it does mean further generalization, and proper generalization is accurate

in so far as correct placement of the generalized features is concerned. The engineer therefore will do well to consider map generalization (see "Detail and generalization," p. 183), and largely in the degree in which he can apply its principles will his map serve its purpose by being readable.

Standards in map legibility must needs be largely set by the legibility attainable in map reproduction. To attempt to reproduce a map that contains more detail than can be legibly engraved or otherwise reproduced is obviously uneconomical, and in consequence a topographic map should be inked with the possibilities and limitations of engraved or other reproduction well in mind and with full allowance for the scale of reproduction. To plot more detail in the field than can be legibly inked in the office or legibly reproduced in the press room is likewise uneconomical, and as a consequence the field engineer should make his survey, plot his observations, and pencil in his map with the probabilities and limitations of office drafting and inking fully in mind and also with due allowance for the appearance of the final map when printed.

*Legibility of map reproduction.*—First consideration should be given to the possibilities of engraving or other form of reproduction to be used. Most of the topographic maps published by the Geological Survey are engraved on copper, separate plates being used to represent the culture, relief, and drainage. Transfers from the three engraved plates are made to three printing plates (either stone, zinc, or aluminum), from which the map is printed in three colors. The legibility of the printed map is increased in part by the sharpness of the engraved lines, which are faithfully reproduced in the printing, and in part by the contrast afforded by the three colors used to distinguish the principal classes of map features. Legibility of reproduction is further increased by good lettering that has been placed in favorable positions for reading and so placed as to avoid unduly covering the map features. The legibility of a printed map is decreased by excessive detail in map expression and by inferior map reproduction.

The legibility with which engraved lines may be reproduced (pl. 17) determines the character of the engraving. For example, if engraved lines are cut too close together their printed reproduction will be "mashed," and if lines are cut too lightly there may be uncertainty in their transfer and printing. Engraving must therefore conform to that which can be legibly reproduced. It is possible, however, to engrave and to print so much detail that the final map may be overloaded and its legibility impaired. This possible condition should be foreseen and prevented so far as practicable, and field work should ordinarily not be executed in more detail than can be reproduced with legibility on a map that is easily readable.

*Legibility of office inking.*—The standard of legibility for the inking of topographic maps should be based wholly upon quality for reproduction. If the map is to be engraved the inked copy for the engraver need be accurate and legible only, and as a consequence finely executed and expensive drafting may for the greater part be avoided. If the map is to be reproduced by photolithography for regular publication the inking must be done with the utmost care and refinement, inasmuch as any defect in the drawing will be repeated in the photolithograph.

The engraver's need for inking legibility is twofold. First, the map should be so legibly inked that when it is transferred to copper—a process involving photography, transfer to zinc, and a wax impression from the zinc to the copper plate—the transfer itself will be legible to the engraver. Second, the map should be so legibly inked that the engraver can easily read it as he constantly refers to it and also that he can pick out with certainty those features that are to be engraved separately on the plates representing the culture, drainage, and relief, inasmuch as the entire map is transferred to each plate.

Inking legibility is increased by the use of the best paper and inks. The inks used must have strong photographic value and should not smear or run. The symbols used, especially those representing the culture, should be so drawn and spaced that when they are transferred to the copper plates they will be of approximately the standard gage for engraving. Legibility for the engraver is further increased by the omission of certain lines in the inking not needed as copy and only tending to clog up the transfer. (See last paragraph under "Character" [of inking], p. 278, and "Cliffs," p. 295.) The inking topographer will do well to bear in mind that he is preparing copy for the engraver rather than an artistic drawing for an exhibit.

*Legibility of field penciling.*—The standard of legibility for field penciling should be based first upon furnishing clear copy for the inking topographer or draftsman, and then upon furnishing only such copy as can be legibly engraved and reproduced. The field sheet should be so legibly penciled that the office inking may proceed with assurance and dispatch, with no doubt as to the interpretation of the copy. The engineer who excels in ability to draft fine lines, however, should be watchful lest he overrefine in detailed expression and produce intricate pencil copy that will call for more skill in inking than may be available or for more detail in engraving than can be legibly reproduced. The topographer should also bear in mind that illegibility in field penciling can be overcome in the office only at the expense of accuracy, and that any overrefinement in detail can be overcome only at the expense of a forced generalization of features in the inking, or in the reproduction, or both. Legibility in penciling requires sharp, fine lines that can be made only by a sharp hard pencil,



evenness of appearance in each line, avoidance of crowding, avoidance of dirt or other soiling of the paper, and the use of such spacings and symbols as will most nearly approximate those that are to be inked on the final drawing. The engineer will also need to learn to use a rubber eraser with a minimum of injury to the surface of the paper.

*Legibility through neatness.*—The legibility of a penciled field sheet may be strikingly increased by neatness and care in the handling of the paper. The use of cover paper of a soft color such as manila will not only aid in keeping the sheet clean but will also relieve the eyes from the glare that is reflected from a wide exposure of clean white drafting paper. If the plane-table sheet is kept mostly covered and portions exposed by means of openings cut into the cover paper only where needed for the day's work (and afterwards pasted over), much dust and dirt will be excluded. Additional dust protection may be obtained by having the cover paper a little larger than the plane-table sheet and folding the edges under the drawing paper. The hands and fingers should touch the paper as little as possible, inasmuch as moisture and oil from the skin may either leave permanent marks or serve as a collecting agent for dust that may afterwards be rubbed in. A sheet of paper or a dry handkerchief may be advantageously used as a rest for the hand, and in warm weather this precaution is imperative in order to keep the sheet clean. Grease spots, dirt, and superfluous soft penciling are all highly photographic and in addition to obscuring the legibility of the essential penciling are serious hindrances in photography, first in the advance-sheet photolithography and finally in the photographic processes used in transferring the map to copper.

#### CARE OF INSTRUMENTS

Too much emphasis can not be laid upon the importance of care in the handling and transportation of instruments. Every employee intrusted with instruments in the field will be expected to keep them clean and in adjustment, to protect them from undue wear, and to return them to the custodian in fit order for use.

*Minor repairs.*—Each topographer should provide himself with a few simple tools and supplies, such as a small pair of pliers with side wire cutter, screw drivers of two sizes, small flat and round files, a spool of soft copper or brass wire, a few assorted brass nails and screws, a bottle of oil, a bottle of liquid shellac, spider web, and plaster of Paris, all of which may be used for minor repairs to instruments. Field work should never be delayed by sending an instrument away for repair if the topographer can possibly repair it himself. Even crude repairs may often be made to serve until a new instrument can be procured.

*Setting of bubbles.*—For setting level bubbles a small supply of plaster of Paris should be kept on hand. For use the plaster should



be mixed with water to the consistency of a thick paste. If plaster is lacking, strips of paper may be used, but these should never be jammed in very tight, as the pressure may distort the glass and thus vitiate the bubble reading by an appreciable amount. A reflecting surface of colored paper should be placed under the bubble in order to make the graduations more readable; a subdued green or blue tint is recommended.

*Mounting of cross wires.*—For mounting cross wires a small bottle containing shellac dissolved in alcohol, a pinch of beeswax, and a pair of dividers or a forked stick are needed. The best spider web is of course a freshly spun one from a small spider, for this will be both clean and elastic; but as spiders are not always available, it is well to keep on hand a spider cocoon. Such a cocoon will furnish webs enough to last for years, although with age the threads become stiff and brittle and therefore more liable to break from a jar to the instrument. Most webs taken from grass or bushes are rough, coarse, and dirty.

To draw the reticule from the instrument, unscrew and remove the eyepiece slide; then take out two opposite capstan-headed screws and loosen the other two. Using the latter two as handles, revolve the cross-wire ring  $90^\circ$ , insert a pointed stick through the end of the telescope tube into a screw hole in the ring, and, using it as a handle, remove the other capstan screws and draw out the ring. To replace it in the telescope, reverse this procedure. When in place the cross wires should be on the side of the ring toward the eyepiece.

Having pressed a bit of beeswax to each prong of the dividers or forked stick, let a small web fall from the end of one of the prongs, or pick with it from a cocoon a single thread, pressing the thread into the beeswax, stretch the thread moderately and attach to the wax on the other prong. If an old web is used, it should first be dampened by dipping in water for a few seconds. In place of the dividers or forked stick, small sticks or lumps of wax may be attached to the web about 2 inches apart. Place the web across the reticule, using a magnifier to insure its coinciding exactly with the marked lines. Put a small drop of shellac on each end and leave until dry.

*Cleaning instruments.*—Instruments having working parts exposed to air and dust require cleaning from time to time. Such exposed parts as the threads of tangent screws are particularly liable to collect dust and grit and should be wiped frequently with an oily rag and then rubbed dry. Only the best quality of clock or watch oil should be used for this purpose. Steel tapes should be cleaned and oiled after use. All moisture or grit must be wiped from them each time they are reeled, or they will deteriorate rapidly. Neither the object glass nor the eyepiece of a telescope should ever be rubbed with rough cloth or with the fingers, as the glass may thus be per-

manently scratched. The lenses should never be removed from the cell that holds them nor separated from one another.

*Packing and shipping.*—In shipping instruments by freight or express alidade boxes must be filled in with paper or cloth, so that if any part of the instrument should jar loose during the journey it will not roll around in the box and damage other parts. Heavy articles, such as compasses, aneroids, or other small instruments, should never be placed in the instrument box. On no account should any instrument be shipped by express or freight in its own case only. A wooden box, large enough to permit a generous amount of excelsior, hay, or other padding around the instrument case, should be provided. The same precautions should be taken when these instruments are to be transported by pack train. Under such circumstances the instrumental outfit is most conveniently carried in a pair of canvas pack bags (alforjas), which must be properly balanced. A canvas pack cover should be thrown over the whole and tucked in on all sides.

*Protection.*—When in camp instruments, plane-table boards, tripods, and rods should never be allowed to remain outside overnight, exposed to dew or rain. It should be the regular practice in every field party to place all instruments under shelter as soon as they are brought in at the end of the day.

## ADJUSTMENT OF INSTRUMENTS

### PRECAUTIONS

The object glasses and eyepieces of all instruments must be properly focused. The cross wires projected against a distant object should appear immovable when the eye only is moved. Before the adjustments are commenced the instruments must be firmly set up and leveled. An instrument may appear to be out of adjustment simply because some part is loose. The object glass may be partly unscrewed or an adjusting screw may be only partly tightened; level bubbles or cross wires occasionally become loosened. Therefore, before commencing the adjustment of an instrument look out for such defects. When it is thought that an adjustment has been completed, always test it before using the instrument. All adjusting screws should be screwed tight enough to hold, yet not so tight as to injure the threads or put a severe strain on any other part. Especial care should be taken not to strain the cross-wire screws.

## TELESCOPIC ALIDADE

The principal adjustments for the telescopic alidade (pl. 11, A) are for level and collimation. These should be tested daily.

*Level.*—Whenever a new vial is inserted in the tube of the striding level an adjustment for side swing should be made. Unscrew the pin that holds the level on the telescope; place the striding level in position, and bring the bubble to the center of the tube by means of the tangent screw; rock the striding level from side to side through an arc of about  $10^\circ$ . If the bubble stays in the center the adjustment is perfect, but if not, bring it to the center by means of the side adjusting screws. Then replace the pin.

Clamp the telescope, bring the bubble to the center of the tube with the tangent screw, lift up the level carefully, reverse, and replace it on the telescope. If the bubble runs away from the center, bring it halfway back by means of the tangent screw and the other half by the adjusting screw at one end of the level tube. Repeat this operation till the bubble stays in the center after reversal.

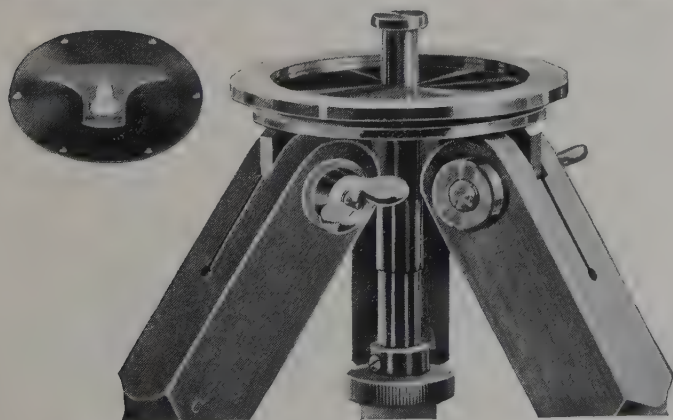
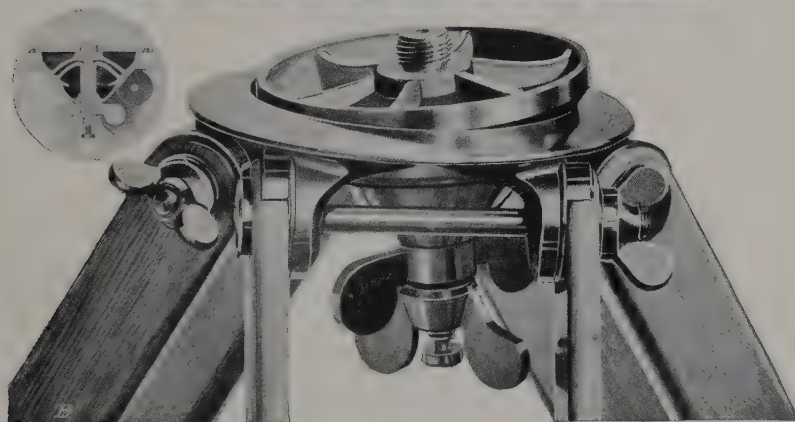
*Collimation.*—With the alidade standing on a level surface test the verticality of the vertical wire by setting the wire on a near-by point and raising and lowering one end of the telescope to see if the point remains on the wire; or by setting the wire on a vertical corner of a building or on a plumb line and raising and lowering the telescope to see if the wire always coincides with the vertical line. If the wire is found not to be in true vertical position, loosen the screws and by a slight shift in the position of the cross-wire ring bring the vertical wire into true vertical position. Point the telescope on a small but well-defined object about half a mile distant and while watching this through the telescope revolve the telescope  $180^\circ$  in its supporting sleeve. If the intersection of the cross wires remains centered on the object, the adjustment is perfect; if not, change the cross wires for half the error and repeat the operation until they stay on the point selected.

*Ruler.*—So long as but a single alidade and but one edge of the ruler are used, it makes no difference in the results whether the edge of the ruler is parallel to the line of sight or not, except for use with the Baldwin solar chart, when a correction must be applied if appreciable.

*Circular level.*—Place the alidade on a level surface. Bring the bubble to the center of the glass by means of one or two of the three adjusting screws.<sup>1</sup>

*Side level with adjustable vernier.*—A type of alidade now on the market, which in the near future may be generally adopted (pl. 11,

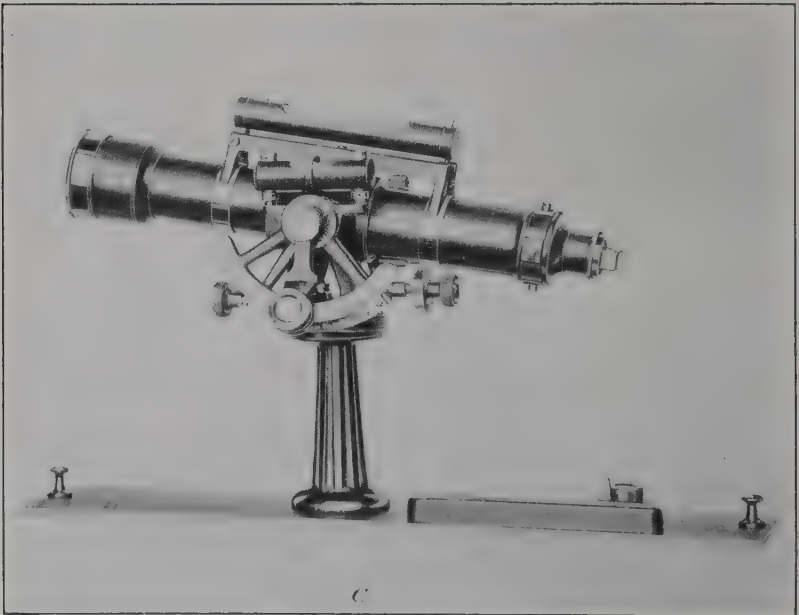
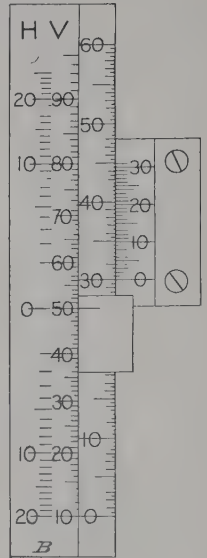
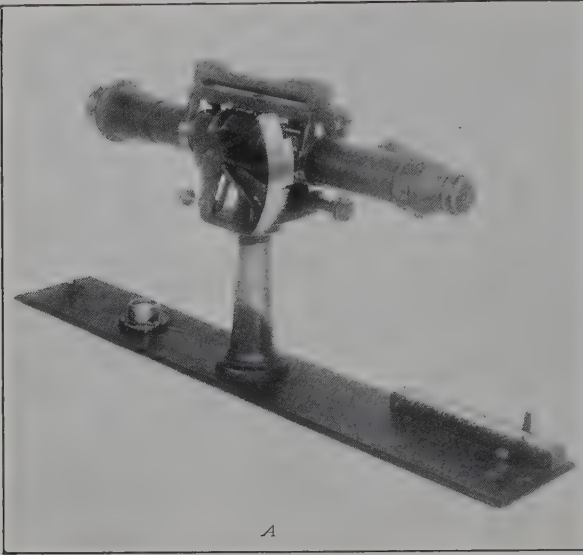
<sup>1</sup> The second table on p. 407, Bulletin 650, is erroneous. The right-hand column should be minutes and seconds instead of degrees and minutes.



PLANE TABLE AND TRIPODS

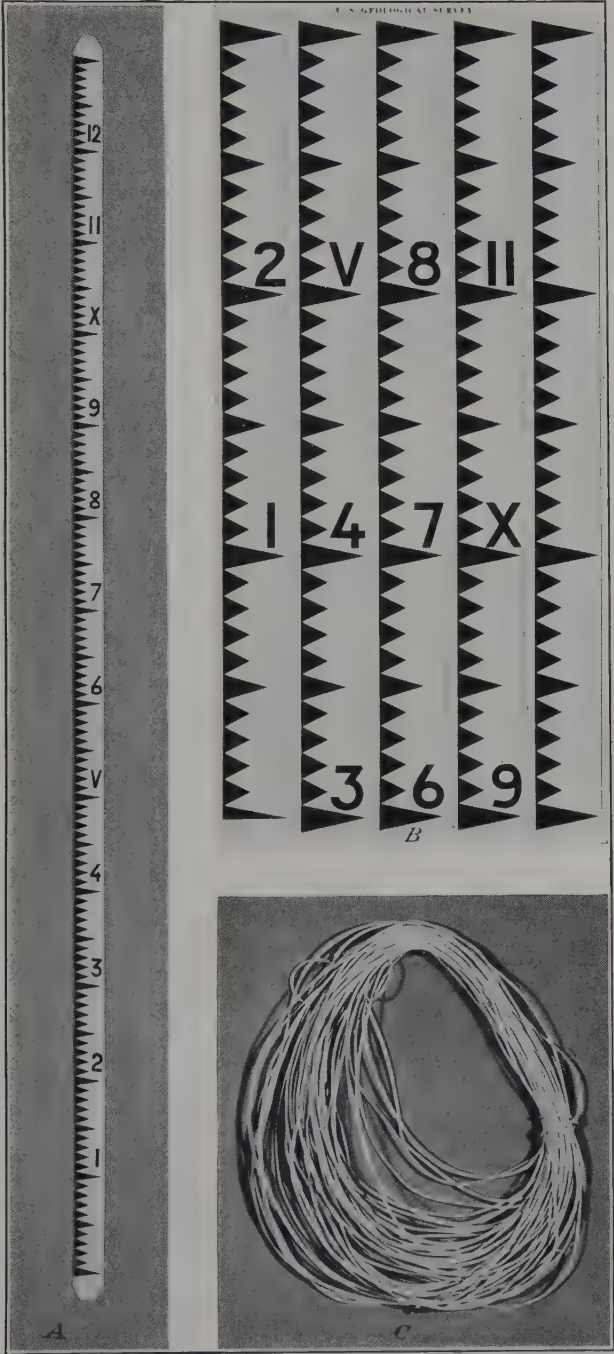
*A*, Plane table; *B*, Johnson tripod head; *C*, Traverse tripod head





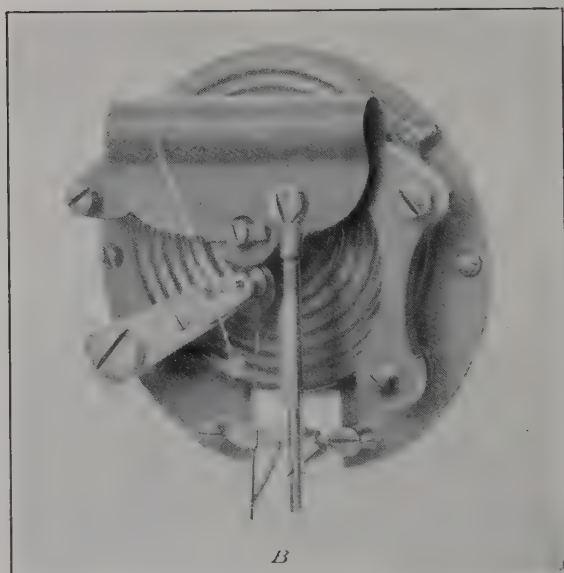
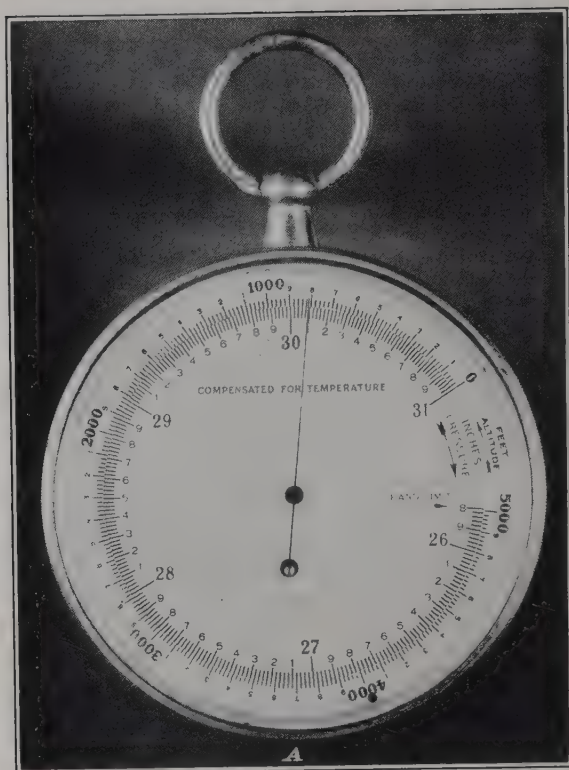
TELESCOPIC ALIDADES

A, Standard alidade; B, Stadia arc graduations; C, New standard alidade



STADIA ROD AND ROPE

A, Stadia rod; B, Stadia-rod sheet; C, Twisted rope



ANEROID BAROMETER

*A*, Face of aneroid; *B*, Internal mechanism

C), has a movable vernier arm with a side level attached. The advantage of this type is that in reading vertical angles only one setting is necessary and the level reading is always the same—generally  $30^\circ$ . To adjust this vernier level, place the alidade on a horizontal surface. Level the telescope by means of the striding level which has been previously adjusted. Set the 0° of the vernier opposite the  $30^\circ$  mark on the arc. Turn the adjusting screw at one end of the level tube until the bubble is in the center. The 0 position for some alidades may be opposite the  $15^\circ$  mark and capstan-headed nuts may be used in place of screws.

To fix an accurate level surface, proceed as follows: Place the alidade on a plane-table board or other adjustable surface which is approximately horizontal. After having adjusted the striding level, place it on the telescope and bring the bubble to the center by means of the tangent screw. Turn the alidade  $180^\circ$  and then  $90^\circ$ . If the bubble remains in the center of the tube for both positions the adjustment is perfect and the surface is level. If not, bring the bubble halfway to the center by the tangent screw and the rest of the way by moving the plane-table board. The circular and side levels may then be adjusted if necessary.

#### COMPASSES

Compasses will usually be out of balance when transported to a different locality. The sliding weight must be moved when it is so much out of balance that one end of the needle is near the glass cover when the box is leveled. Many complaints have been made that compasses were worthless, when the only trouble was that the needles were so badly out of balance that they rubbed against the glass covers.

It should be a strict rule with everyone using a compass to lift the needle from the center pin immediately after use. Under no circumstances should a compass be carried from one station to another with the needle resting on the center pin. Party chiefs should lay special emphasis on this rule when instructing new field assistants.

#### TOPOGRAPHIC MAPPING METHODS

##### CONTROL

The initial control as outlined below, upon which the surveys for topographic maps are based, is described in detail in parts B, Triangulation; C, Transit traverse; and D, Leveling. (See also "Standards for field work," p. 181.)

Surveys for topographic maps must be horizontally controlled by means of locations that have been determined either by theodolite triangulation of the first, second, or third order or by transit traverse,



and some maps are controlled by means of both triangulation and transit-traverse locations.

Surveys for topographic maps must also be vertically controlled by means of elevations that have been established by lines of spirit levels of the first, second, or third order.

The further horizontal control on which the survey of the details of the map is to be based will be obtained by means of plane-table triangulation (p. 197) or plane-table traverse (p. 205) or by both combined. These forms of control also provide supplementary vertical control through the use of vertical angles measured with the telescopic alidade. Supplemental horizontal control may also be obtained by means of the aerial photographic methods referred to below.

#### AERIAL PHOTOGRAPHIC BASE

Part F, "Map compilation from aerial photographs" describes aerial photographic methods for obtaining supplemental control, a partial culture and drainage base, and nearly complete woodland and marsh outlines for topographic maps. Such procedure promises increasing usefulness as the photographs and the methods of using them are further improved. The initial horizontal control needed for the adjustment of aerial photographic map data is similar to that specified above for the control of topographic surveys. (See "Mapping on aerial photographic base," p. 254.)

#### TOPOGRAPHIC MAPPING INSTRUMENTS

Theodolites, transits, and levels, as described in parts B, C, and D of this manual, are not employed in detailed topographic mapping but are used in the initial control operations. Exceptions may occur where a control level party is attached to a topographic party or where there may be need for spirit levelling of the fourth order, sometimes referred to as "fly" levels. The instruments used in topographic mapping are chiefly the plane table (pl. 10), telescopic and sight alidades (pl. 11), stadia rod (pl. 12, A), compass, aneroid (pl. 13), tape, field glasses, and plotting scales (pl. 9). Complete lists of instruments and accessories needed for different kinds of topographic mapping will be found on pages 44 and 45 of part A.

*Plane table.*—The surveys upon which the topographic maps published by the Geological Survey are based are executed by means of some form of the plane-table method. The plane table (pl. 10, A) consists essentially of a drawing board that is supported by a tripod and used in connection with an alidade (pl. 11). The board can be leveled and also turned in any horizontal position and can be clamped when properly set. When in use the plane table and its support must never move; and the greatest care must be taken that when it is once set

or oriented it shall not be disturbed in position. The engineer must not lean on it or against it. On the board is fastened the drawing paper upon which the map is to be plotted. (See "Plane-table paper," p. 166.) Detailed topographic mapping is usually executed on a plane-table board that measures 18 by 24 inches (pl. 10, *A*); plane-table triangulation is done on plane-table boards that measure 24 by 31 inches; for plane-table traverse boards either 15 by 15 inches or 18 by 24 inches are employed, although some traversing in dense timber or in brushy areas is done on a board that measures 9 by 9 inches.

Two types of alidade are used, the telescopic (pl. 11, *A*) and the sight (pl. 9, *B*). The sight alidade is used only for paced or tape traverses; for all other mapping the telescopic alidade is used. The alidade is used as a means of sighting the direction of topographic details which are to be located on the map, and immediately after each sight is taken the corresponding direction line is drawn on the plane-table sheet by running a pencil edge against an edge of the ruler which is rigidly attached to the sighting part of the alidade.

Two types of tripod are used. The one in most common use (Johnson type) (pl. 10, *A, B*) has a universal leveling movement for a rapid leveling of the plane-table board and combines rigidity of construction with comparative lightness. A lighter form (pl. 10, *C*) is also used for foot and tape traverses for which the leveling is done with the tripod legs.

*Other instrumental outfit.*—Stadia rods (pl. 12, *A*) are used in connection with stadia wires that are set in all telescopic alidades. Stadia rods are divided into feet and suitable graduations thereof, and the rods are generally used in 10, 12, or 14 foot lengths and may be hinged in the middle for convenience in carrying. The stadia wires of the alidade are set to intercept 1 foot on a rod 100 feet in front of the object glass of the telescope.

A box compass is fastened to the ruler of each telescopic alidade. The compass is used as a means of orienting the plane-table board in traverse work and also as an approximate means of orienting the table prior to the determination for position by the three-point method.

The use of the aneroid (pl. 13) is fully described on pages 214–219. Two types of tape are used, a 50-foot metallic tape for miscellaneous use and a 300-foot or 528-foot linen tape or braided rope for certain traverse lines. (See "Tape traverse," p. 211.)

#### PLANE-TABLE TRIANGULATION

*Definition.*—Plane-table triangulation consists in the location of many points on a plane-table sheet (representing tie points distributed over the area that is to be mapped) through the use of the so called pure plane-table methods. (See pl. 10, *A*.) These methods, in

principle, involve only the use of the plane table and the telescope alidade, and in theory the operations may be executed by one man. In practice one or more assistants are employed and auxiliary methods such as stadia are used. The area that is to be mapped is outlined on the plane-table paper by means of a projection (see p. 166) on which the initial horizontal-control points have been plotted. Plane-table triangulation starts from these control points, and by means of the plane-table methods of intersection and resection the necessary points on which to tie the topographic details of the map are "cut in" or located on the paper.

*How used.*—The results of plane-table triangulation are utilized under one of two general plans, or both combined. (a) The points that have been located on the paper by the plane-table triangulation are transferred to smaller plane-table sheets (usually one-half size) on which the final map is to be drawn, and the subsequently executed plane-table traverse lines are tied to the points thus transferred. (b) The original plane-table triangulation sheet may become the final sheet on which the map itself is drawn, and this procedure is the practice in mountainous areas that are sufficiently open to permit detailed topographic mapping by plane-table methods alone. (c) In regions that are sufficiently open for detailed plane-table triangulation the two plans outlined above may be combined, the details of mapping being obtained by traverses and by stadia measurements, and supplementary control being obtained where it is needed by means of additional plane-table triangulation.

*Preparation.*—Before the projection for the map under consideration is prepared a thorough study of all the geodetic positions available for the control of the area should be made, and the position of the projection on the paper should be so arranged as to include the greatest possible number of desirable positions.

*Projection.*—The projection should be made with the utmost care on seasoned double-mounted paper, and the positions should be plotted thereon as accurately as possible. The projection and all positions should be satisfactorily checked. Metal-mounted sheets should be used for plane-table triangulation whenever practicable. (See "Plane-table paper," p. 166; "Construction of projections," p. 166; and "Plotting horizontal control," p. 177.)

*Precautions.*—In the field the plane-table sheet should be protected by cover paper as much as practicable and should be firmly attached to the plane table by brass thumbscrews or tacks, to reduce to a minimum the expansion or contraction caused by changes in climatic conditions. In windy weather a weight should be suspended from the head of the tripod to steady the plane table and to prevent a possible accident. The use of a large umbrella, if the sun is bright,



facilitates the work and is a protection to the eyes and the paper. The instrument and paper should be kept clean of sand and grit.

*Alidade.*—The adjustment of the alidade for collimation (see p. 194) and parallax should be carefully inspected before commencing work and watched thereafter to be assured of its good condition at all times. (See "Adjustment of instruments," p. 193.)

*Signals.*—Substantial signals, of whatever material is at hand, should be erected on the main triangulation stations and on other prominent hilltops according to necessity. If the use of flags is essential, red and white cotton make good material. Use white if the flag is to be observed against a dark background and red if it stands against the sky. While the signals are being placed every opportunity should be utilized to learn the topography of the country, to select the best subsidiary stations, to mark their approximate location on the guide map, and to fix in mind the distinguishing features of objects most likely to be seen from the stations to be occupied.

*Choice of station.*—In choosing the first station to be occupied it is best to select one of the most prominent triangulation stations, located preferably in the southern part of the quadrangle, so that when most of the sights are taken the observer will be looking away from the sun. In this way objects may be more clearly seen and peculiarities noted. Clear atmosphere is essential when the first stations are occupied.

*On the station.*—After leveling the plane table, place the alidade on a line connecting the station occupied with one of the triangulation points farthest away (the other end of the base), revolve the table until the farther signal is bisected by the vertical wire of the alidade, and clamp the table. Verify the orientation by sights to additional visible triangulation stations. Now make the circuit of the horizon systematically and take foresights to prominent objects, such as signals, cupolas, towers, chimneys, flag poles, monuments, windmills, church steeples, and definite points on schoolhouses, dwellings, barns, silos, trees, hilltops, or spurs. Draw the lines of sight with a chisel-edged 9-H pencil, to considerable length along the square edge of the alidade, being careful always to hold the pencil at the same angle, and to see that the contact of rule and paper is perfect. Get azimuths of long, straight stretches of road and railroad whenever possible. Stadia may well be used to locate road forks or objects in the immediate vicinity of the station. From time to time while making observations and on the completion of the work at each station check the orientation of the plane table in order to see if there has been any movement.

*Magnetic declination.*—While the plane-table sheet is oriented, determine and draw the line of magnetic north through the station, and repeat the operation at several other widely separated stations.



*Vertical angles.*—After all the sights have been taken adjust the striding level of the alidade (see “Adjustment of instruments,” p. 193) and read vertical angles to the points whose elevations are desired. Angles that are read to the principal control points in the scheme should be checked. (See “Station elevation,” below.)

*Station elevation.*—The elevation of each plane-table station should be determined by means of vertical angles taken either to specially located spirit-level bench marks or to other plane-table stations whose elevation has been previously determined. In general, the principal stations from which the greatest number of vertical angles are to be taken should be connected by means of reciprocal vertical angles taken under differing conditions, and then the final elevation for each station in the net should be determined by means of a weighted adjustment of the observed differences in elevation. This adjustment should be made in conjunction with such ties with level bench marks as have been made. In measuring important vertical angles, such as those to other stations or to points on spirit-level lines, all readings should be checked by reversing both striding level and telescope and by using different positions of the vertical arc, which may be accomplished by placing a plotting scale or some other flat object under one end of the alidade ruler.

*Records and computations.*—Plane-table stations may be designated by Roman numerals (I, II, III, etc.), and each line of sight drawn on the plane-table sheet by an Arabic numeral. Such designations should be written on the plane-table sheet and also entered in a suitable notebook. Brief descriptions of objects sighted may be noted on the plane-table sheet and written along the line of sight, and complete descriptions should be recorded in the notes. The notebook should also contain the vertical-angle records.

Distances between stations and between stations and located points whose differences in elevation are to be computed will be scaled by means of a boxwood scale of miles provided for the purpose and graduated for the field scale. Computation of differences in elevation is facilitated by the use of prepared tables. Care should be exercised in noting and in allowing for the height above ground both of the alidade and of the point sighted. The proper corrections for refraction should be applied wherever appropriate.

*Other stations.*—When the work on the initial station is completed, repeat the operation on the station at the other end of the base and on as many additional stations as may be necessary to complete the work. If practicable all triangulation stations that have been plotted on the sheet should be occupied. The point of intersection of lines drawn to the same object determines its location, but all intersections should be verified by a sight from a third position.

Additional stations may be made at intersected points (see below), at points to each of which a single foresight has been drawn on the plane-table paper (see "Location by resection," below), and at points whose location may be determined by the "three-point method" (see p. 202).

*Suggestions.*—A signal should be erected where necessary to mark the place of a station for future reference. Care should be taken to prolong on the plane-table sheet a line that may later be used for an orientation. In areas of great relief and of difficult access advantage should be taken of every opportunity to contour, even approximately, topographic features, such as bottoms of canyons, rock exposures along canyon walls, ground surfaces in heavily timbered, inaccessible mountain gaps, and indefinite slopes of mountain masses that may not practically be occupied by the plane table.

*Number of points.*—Enough locations should be made to furnish satisfactory control. The number necessary is determined by consideration of the character of the country, the amount of supplementary plane-table traverse, and the scale of the work.

#### STATIONS AT INTERSECTED POINTS

In occupying a point whose location has been determined by means of sights taken from previously made plane-table stations the orientation should be made on the stations from which the foresights were taken. If the exact point that has been located can not be occupied proper allowance must be made for any plottable distance between the new station and the located point.

#### LOCATION BY RESECTION

The location of a plane-table station may be obtained by the method of resection, which in general is stronger than the three-point method. Location by resection involves two separate operations performed on two different stations, and in practice any length of time may elapse between the two operations. The resection method is of limited use, however, inasmuch as it involves a foresight from a previous station and the erection of a signal on the proposed station point or the positive identification afterward of the point or direction sighted. Foresight lines that are to be used for a location by resection should be drawn on the plane-table paper exactly through the point representing the station from which the sights are taken and to the full length of the alidade ruler. The line through the point representing the occupied station should be light, and care should be taken to hold the chiseled pencil point directly against the ruler. The foresight line need be drawn only through the approximate position of the new station and at the extreme end of the

ruler in order not to add unnecessary lines to the paper. After drawing the line look through the telescope again and also test the plane-table orientation in order to insure that the table has not moved. Similar foresights may be taken to other prospective station points whose locations it is desired to obtain at some future time by resection.

To locate a new station which is being occupied and to which a long foresight has been previously drawn, orient the plane-table sheet by placing the alidade ruler in the reverse direction on the line sighted and swinging the plane-table board until the station from which the foresight was drawn is seen behind the center wire, and clamp the plane-table board. The station being occupied is on this foresight line, and the location is determined by resecting from other plane-table stations whose directions are most nearly at right angles to the foresight line that they are to intersect and whose distance is less than that of the station from which the foresight line was drawn. Center the ruler on the plotted position of one of these stations, swing the telescope until the signal mark at that station is behind the center wire, and draw a line against the ruler to intersect the foresight line. The intersection marks the location of the occupied station. This intersection should be checked by at least one other resection from another station. The two resected lines should cross the foresight line at the same point.

### THREE-POINT METHOD

A plan frequently adopted for the location of plane-table stations is that known as the "three-point method." It can be used advantageously when three or more previously located points properly distributed are visible. Before making three-point stations a compass line should be drawn on the sheet and used for approximate orientation.

In Figure 6 the triangle formed by the three fixed points is called the great triangle, and the circle passing through them the great circle. When the plane table is imperfectly oriented, the lines drawn from the projected points (rays) will not intersect at one point, except when the table is on or near the great circle, but will form a triangle of error. The term "new station" means the place on the ground where the plane table is set up, and the term "point sought" its true projected position on the sheet.

The angle formed by the intersection of the rays drawn from any two of the fixed points is the correct angle, the problem being to shift the orientation of the plane table so that the vertices of the several angles come together in a common point, which will be the point sought. This fact is the basis for the tracing-paper solution of the three-point problem, which is described under the next heading.

If more than three known points are visible, select the three that will give the best results, preferably the three that will form a triangle embracing the new station. Do not try to use more than three at once. Orient the plane table by magnetic compass, and draw rays from the three known stations. If a compass line is not available or if there is considerable magnetic attraction, adopt an approximate location of the point sought, place one end of the alidade ruler on the point thus adopted and the other end on the most distant of the points used, revolve the plane table, sight the most distant point used, clamp the table, and draw rays from all three points. On the first trial a triangle of error will undoubtedly result, owing to improper orientation of the table.

If the new station is on or near the great circle, its position can not be determined from the three fixed points selected, and one of the three should be replaced by a fourth. (See fig. 6, 2.)

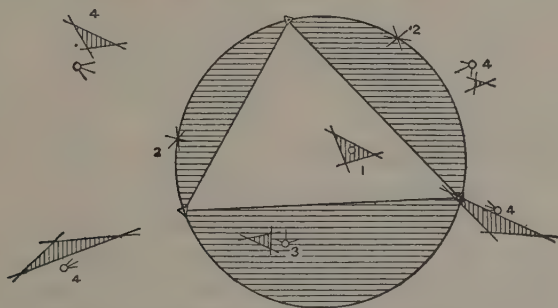


FIGURE 6.—Graphic solution of three-point problem

If the new station is within the great triangle, the point sought is within the triangle of error and in the same relative position in the triangle of error as this small triangle bears to the great triangle. (See fig. 6, 1.)

If the new station falls outside of the great triangle, the point sought is either to the left of all the rays or to the right of them all. Of the six sectors formed by the rays, there are only two in which this condition is fulfilled.

If the new station falls within one of the three segments of the great circle formed by the sides of the great triangle, the ray drawn from the middle point lies between the point sought and the intersection of the other two rays. (See fig. 6, 3.)

If the new station is without the great circle, the point sought is always on the same side of the ray from the most distant point as the point of intersection of the other two rays. (See fig. 6, 4.)

Under either of the two conditions stated just above, where the new station is outside the great triangle, the exact position of the



point is determined by the condition that its distance from the several rays must be proportional to the length of the respective rays. Make a new approximation of the point sought and repeat the process, orienting on the most distant point. If the second trial results in a larger triangle of error, the trial point has been taken in the wrong direction from the ray from the middle point if within a segment and from the most distant point if without the great circle.

In practice the topographer estimates the relative distances of the three fixed points from him and marks the position of the trial point a proportionate distance from the three rays that form the triangle of error. The alidade is then so placed that it exactly cuts this trial point and the plotted position of the most distant point, and the plane table is turned so that the line of sight bisects the most distant point. The table is then clamped. A short ray is drawn through the trial point, and the other stations are sighted and short rays drawn toward them. If the three intersect in a common point, it is the point sought, and the plane table is oriented. If a new triangle of error is formed by the rays, the operation must be repeated. The final location should always be checked where possible by sighting a fourth point.

Points whose location has already been determined and which can be seen from any one point are usually few. However, where the available control is sufficient to permit a choice of points, a selection of three points that will place the new station within their great triangle will give the most accurate location of the point sought. The next best location is obtained where the new station is nearly on a line between two known stations, one of which is at a considerable distance, so that the two rays will nearly coincide, and where a third known station lies at a moderate distance and in such a position that the ray drawn toward it will be at approximately right angles to those toward the other two. Where these conditions do not exist the selection of three points of which the middle one is nearest to the topographer will place the new station definitely outside of their great circle and will eliminate the danger of an indeterminable location.

Bessel's, or the Italian method, as it is sometimes known, and the inverse triangle method, used by the French, offer no advantages over the methods already described and involve the use of more construction lines. They are therefore not used.

For a detailed discussion of plane-table methods, see "Plane-table manual" (United States Coast and Geodetic Survey Special Publication 85), or standard texts on surveying, such as "Higher surveying, volume 2," by Breed and Hosmer, or "Topographic surveying," by Herbert M. Wilson. For mathematical solution of the three-point problem, see United States Coast and Geodetic Survey Report

for 1880, appendix 13; idem for 1897-98, appendix 13; or United States Geological Survey Bulletin 650.

#### TRACING-PAPER SOLUTION

By another method a piece of tracing paper is fastened securely to the plane table, and the three or more located points visible are sighted and rays drawn toward them from a fine point upon which the alidade is carefully centered for each ray. The alidade is then removed. The tracing paper is released and so shifted over the plane-table sheet that the rays drawn toward the points sighted pass through their respective plotted positions simultaneously. The point at the intersection of the rays (the pivot point) is then exactly over the position on the plane-table sheet of the point sought and should be pricked through the tracing.

Locations made by the tracing-paper method are likely to be less accurate than those made by the graphic method, described above. They should be checked after they are pricked through to the plane-table sheet before using them in the location of other points. In general, this method should be used only when special conditions make it necessary, or as a means for locating a trial point for the graphic method.

#### PLANE-TABLE TRAVERSE

##### METHODS

Traversing consists of much more than getting direction and distance, though these are absolutely essential features. All the essential topographic features on each side of the line are to be obtained at the time the traverse is made.

Accuracy of plane-table traverse depends on two factors—namely, the obtaining and plotting of distances and the orientation of the plane table.

Distances are obtained by stadia, wheel, tape, or pacing, and the orientation is made by magnetic needle, by back and fore sights, by the Baldwin solar chart, or by other approved solar apparatus.

When the needle is used the accuracy of orientation is dependent on the freedom from local attraction and the length of the needle. For these reasons it is well to avoid the use of the compass near railroads, electric-transmission lines, or large bodies of steel or iron, and in volcanic regions. No plotted line should be greater than the length of the needle.

The method employed in determining distances will be governed by the character of the country and the scale of the work. Traverse lines should be run along roads, ridges, or streams, or at intervals in timbered country when necessary; the method in general practice

when the needle is used is to set up at alternate stations, using intermediate stations as turning points. Sights should be taken from these stations to prominent hilltops, spurs, houses, windmills, lone trees, and other conspicuous objects, and these should be intersected at subsequent stations. Following this plan, the traverseman should locate all railroads, roads, trails, houses, churches, schools, and bench marks, all State, county, township, and city boundaries, also all cultural features as listed on page 229.

Streams near the roads should be mapped as accurately as the skill and experience of the traverseman will permit. Especially should stream crossing and recrossing roads traversed in ravines or gulches be located and junctions shown with side streams.

In traversing railroads frequent locations by the three-point method should be made if possible, and the line extended by means of fore and back sights. If this is not practicable and it becomes necessary to rely on the needle, it is important to set up the plane table a sufficient distance from the rails to prevent their influence on the needle. The distances can be obtained advantageously by measuring a rail and counting the number of rails between stations.

Where traverse is extended along roads over which levels have been carried, note elevations marked on fences, at summits, bridges, corners, etc., and record them on the traverse sheet. Names of villages, streams, hills, etc., should be obtained in the field as far as possible—especial care being taken to get correct spelling—and should be written plainly on the traverse.

Traverse should not be made to close but should show the two tie points by a double arrow between them; such junctions should not be made in towns or villages.

Traverses should extend a sufficient distance beyond the edge of the quadrangle to overcome any possible error that may occur in the adjustment.

Single-mounted paragon paper is ordinarily used, though celluloid may be substituted to advantage in wet weather. Before using the sheet the name of the State and quadrangle, the date, the name of the traverseman, and that of the chief of party should be written in the lower left-hand corner.

The proper method of plotting is to place the fractional scale division on the old point and prick the new location with the needle at the even division at the end of the scale. This operation should be performed with the greatest care, as more closure errors are to be attributed to careless plotting than to any other cause. (See pl. 9.) When aneroids are used the elevations should be recorded on the sheet at road and stream crossings, divides, and traverse stations. To insure accuracy the aneroid should be compared and corrected with bench-mark elevations whenever possible.

## STADIA TRAVERSE

In plane table and stadia traverse instrumental measurement of distances and elevations gives sufficient control to permit considerable sketching to be done on either side of the line.

*Determination of elevations.*—If the elevations are determined by means of vertical angles taken from the plane table ground elevations may be carried by using a mean height of instrument ( $4\frac{1}{2}$  feet) as a turning point on the rod, or ordinary level notes may be used with H. I. computations. Accurate distance readings are essential, and sights for turning points should not be over 1,000 feet, unless under exceptional circumstances. In large-scale detailed work 300 feet is a better limit. When the lower hair comes near the ground on long sights serious errors are liable to occur at certain hours of the day through refraction. The Anderson or Johnson stadia tables are probably the most satisfactory for computing differences of elevation and horizontal correction. On scales of 1:48,000 or larger the horizontal correction can be readily shown in plotting. On larger scales it becomes important. Angular measurements exceeding  $15^\circ$  should be avoided.

In setting with any tangent screw (whether setting for a zero reading of the arc or sighting a point) turn in the direction that compresses the spring against which it works. If the screw needs to be turned back, instead of turning it to the exact setting, turn it back too far and then bring it up to the accurate setting with a clockwise or right-hand motion, thereby insuring a firm bearing of the spring against the screw. Failure to observe this rule is the cause of many errors in elevation.

Wherever possible, as in regions of low relief, elevations should be determined by using the alidade as a level and the rod as a level rod.

*Beaman stadia arc.*—The use of vertical angles may be avoided by the use of the Beaman attachment to the telescopic alidade. (See pl. 11, A, B.) This attachment consists of a stadia arc, which is screwed on the outer side of the old arc and which carries two separate double scales having coincident zero points marked 50 and 0, respectively. Either scale is read by reference to the common adjustable index, which, when the telescope is level, must be set at the zero point of the scales before the stadia arc is used. The two scales (pl. 11, B) are:

To the right, next to the index, a multiple scale, with zero point marked 50, which indicates multiples for obtaining differences in elevation. To get desired multiple, subtract 50 from scale reading and use algebraic remainder—for example, if scale reads 56, multiple is  $56 - 50 = +6$ ; if scale reads 47, multiple is  $47 - 50 = -3$ .



To the left, a reduction scale, with zero point marked 0, which gives percentages of correction that may be used, if desired, to reduce observed stadia distance to horizontal.

To determine differences in elevation read the distance subtended on the rod and express in feet (for example, 8.7 = 870 feet). Clamp the telescope and level it. Set the index exactly at 50, by means of the tangent screw back of the arc, and do not touch this tangent screw again.

Then, by means of the customary clamp and tangent movement, raise or lower the telescope until there is brought exactly opposite the index such a graduation on the multiple scale as will throw the middle stadia wire somewhere on the rod, it does not matter where. The arc reading, minus 50, multiplied by the observed stadia distance gives the difference in elevation between the instrument and a known point on the rod—that is, the height on the rod indicated by the middle wire. Settings of both index and arc should be made carefully under a reading glass.

Example: Suppose the observed stadia distance is 6.3 (630 feet) and the telescope is so inclined that the multiple scale reads 58; at this exact setting the middle wire on the rod reads 7.2 (7.2 feet above base of rod); then multiple is  $58 - 50 = +8$ , and computation for a foresight would be

$$\begin{array}{r}
 6.3 \\
 +8 \\
 \hline
 +50.4 \\
 -7.2 \\
 \hline
 +43.2 \text{ feet} = \text{base of rod above H. I.}
 \end{array}$$

If the middle wire were set on H. I. or on the top or other fixed point on the rod and the arc were read by estimation (for example, 54.2) to obtain a multiple, the result would be approximate only; therefore this method is not to be used with this attachment.

If the half-wire interval is read and this reading is then doubled to get the stadia distance, it occasionally happens that no even multiple arc setting that will throw the middle wire on the rod can be found. In this case make an arc setting that will throw the lower wire anywhere on the rod; the middle wire will then be somewhere above the top of the rod. Then take the multiple as read on the arc, but compute the position of the middle wire above the base of the rod by adding one-half the expressed stadia distance (in feet subtended) to the reading of the lower wire.

Example: If the half wires subtend 7.2 on the rod, the distance would be  $7.2 \times 2 = 14.4$  (1,440 feet). If the lower wire cuts the rod 8.7 feet above its base, the computed middle-wire reading would be

$8.7 + 7.2 = 15.9$  feet above the base of the rod. Then compute as before.

The reading of the left-hand arc from the same arc setting, used to obtain the difference in elevation, will give the correction, expressed as a percentage, needed to reduce observed distances to horizontal.

Example: If a multiple-arc setting of, say, 70 has been made for difference of elevation work, the reading of the reduction scale would be 4, or 4 per cent. (Reading to the nearest unit per cent is usually sufficient.)

If the observed distance was 12.0 (=1,200 feet), then 4 per cent of 1,200 = 48 feet;  $1,200 - 48 = 1,152$  = corrected horizontal distance.

*Stadia-arc notes.*—Form 9-913A has been prepared especially for Beaman stadia arc notes. The arc reading or multiple (expressed as above or below 50) is placed under the appropriate heading, as in the example below, and all sights are to be regarded as foresights except those taken to determine H. I. The column headed "Product" is for multiple times distance—for example,  $4 \times 4.2 = 16.8$ . The column headed "Rod correction" is for the final reading of the middle wire on the rod.

Date, April 29, 1916. Traverse from Takoma to Sligo.

	Distance	Beaman arc or steps	Product	Rod cor- rection	Difference in elevation	H. I.	Elevation
1							654.7 B.M.
2	4.2	54 or 4	-16.8	+8.2	-8.6	646.1	
3	6.3	48 or 2	-12.6	-4.9	-17.5		628.6
4	9.2	44 or 6	+55.2	+4.3	+59.5	688.1	
5	15.8	57 or 7	+110.6	-13.8	+96.8		784.9

The signs to be affixed to "Product" and "Rod correction" are determined according to whether the observation is a backsight or foresight, by following a rule of universal application, namely:

	Product	Rod correc- tion
Backsight.....	Opposite sign to that indicated by arc reading.....	+
Foresight.....	Same sign as that indicated by arc reading.....	-

The arc reading 54 indicates +; therefore here the sign of the product is - for a backsight and + for a foresight. Another way of determining the sign to be affixed to "Product" is to consider whether the telescope is inclined upward or downward in the direction in which the line is being run when the middle wire is set on "Rod correction." If the angle is upward in the direction in which the line is being run, the sign of "Product" is +. If the angle is downward in the direction in which the line is being run the sign of

"Product" is  $-$ . Note that the sign of "Rod correction" is the same as in leveling. When the line of sight is level the arc reading is 50, and therefore the only entry is rod reading, entered as "Rod correction," whose signs follow the above rule.

*Micrometer eyepiece.*—A micrometer eyepiece for the telescopic alidade has been used for determining distances, and under some conditions, on small scale or reconnaissance work, it has proved of great value. The principle of this attachment is that if two angles and one side of a triangle are known, the remaining parts may be found. The length of the base is known by previous measurement, being a known space on a stadia rod or the distance between two signals left on the ground. The micrometer is used to measure the angles between the lines of sight to opposite ends of the base, and the result is in divisions of the micrometer head. Constants for each instrument are determined,<sup>2</sup> and tables have been prepared to show the number of turns of the micrometer head on different bases to give distances in feet or hundredths of a mile. These tables and constants should be tested on measured horizontal bases of different lengths at the beginning of the season.

In establishing a base for use with the micrometer eyepiece its bearing should be placed on the sheet for future reference. At new

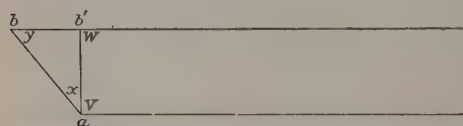


FIGURE 7.—Diagram illustrating correction of base line

station (fig. 7) if the line of sight is not perpendicular to the established base, orient as closely as possible, and draw a line toward one of the signals. Plot the base as

long as the paper will permit. Erect a perpendicular to the line of sight at one end of the plotted base ( $a$ ). Draw a line parallel to the first line of sight through the other end of the base ( $b$ ). Measure the distance of the perpendicular from  $a$  to the intersection with the line through  $b$  on the same scale as the base was plotted. This distance ( $ab'$ ) is the corrected length of base to be used; then  $ab' = ab \sin y$ . The solution depends on the fact that the angle between the lines of sight to opposite ends of the base is so small as to be disregarded, and angles  $V$  and  $W$  are practically  $90^\circ$ . A protractor may be used to make the angle  $y$  between the plotted base at  $b$  and the line  $bb'$  the same as the supplement of the angle  $V + x$  between the plotted base and the perpendicular erected at  $a$ .

The same principle applies to a vertical base, which may be above or below the station occupied.

*Instruments.*—The instruments needed for stadia traverse consist of a telescopic alidade (pl. 11, *A*), with compass attached, a plane table (pl. 10, *A*) not smaller than 15 by 15 inches, with a Johnson

<sup>2</sup> See formula for computing these constants in U. S. Geol. Survey Bull. 650, p. 12, 1924.

tripod (pl. 10, *B*), and a standard stadia rod (pl. 12, *A*). Establish the magnetic north line on the sheet at the beginning of work for future orientation.

It is necessary that the stadia wires give the correct reading on the rod. Therefore, before work is commenced they must be tested on a measured base not less than 500 feet in length, and if an error is found a correction must be applied to each distance measured. It is not desirable to graduate rods to fit the peculiarities of individual instruments.

Correct adjustment for collimation and striding level must be maintained. The eyepiece should give a clear-cut image, free from parallax. To obtain this throw the object glass out of focus and adjust the eyepiece so that the cross wires are perfectly distinct and stationary at every position of the observer's eye.

#### WHEEL TRAVERSE

Revolutions of the wheel may be used for obtaining distances along the traverse line. Tables are furnished to facilitate reduction. A hand recorder may be used as a check on long sights. A record of distances should be kept until closures are made as a check on plotting.

#### TAPE TRAVERSE

In some parts of the country dense forest and undergrowth make it impracticable to carry stadia or wheel traverse, and the lack of open tops puts a narrow limit on triangulation methods. Under these conditions a form of tape traverse depending on aneroid elevations has been devised for obtaining the topography. (See "Aneroid barometer," p. 214.) It is applicable only to scales of 1:48,000 or smaller.

A plane table 9 inches square, with compass attached, and Bumstead tripod are best for the work. A sight alidade, 300 to 528 feet of linen tape or cotton rope (pl. 12, *C*), and a pocket compass are the instruments required. The tape or rope should be marked at 100-foot intervals with red ink in a manner to be clearly understood. It should then be run through hot paraffin and the rear end stiffened to avoid catching and tangling in the brush. It will be necessary to paraffin the tape frequently, especially the rear end, and it should be thoroughly dry to have the best effect. Knots and weak places should be promptly mended with needle and thread.

The chainman should carry a pocket compass, light ax, and marking crayon. He blazes one or more trees at the end of each tape length, and the topographer occupies the point as his next station, thus setting up at every station instead of alternate ones. The sights are taken in the direction shown by the tape and the signal of the



tapeman. It is well to number the stations to avoid error in making closures. Lines should follow natural features, such as ridges, valleys, and spurs, rather than gridiron the territory. The greatest error of the lines comes through the tapeman not keeping a straight course.

Adjustment of aneroid elevations should be made daily (see "Aneroid barometer," p. 214), and the contours altered to agree, care being taken to preserve topographic shape and detail. Adjustment of horizontal errors should not be made on traverse sheets.

#### FOOT TRAVERSE

The method of obtaining distances by foot or animal paces is resorted to in timbered countries and mountainous regions without roads. Careful measurements of the average pace of an animal or a traverseman on a level or a slight incline should be made, and a table prepared in hundredths of a mile.

#### ADJUSTMENT OF TRAVERSE LINES

Large closing errors of traverse lines indicate either a swing in direction due to incorrect orientation or a gross error in reading or in plotting one or more distances. Gross errors in distance should be located between intermediate points of a traverse by running additional traverse lines from them to closing points. By first transferring the lines that fit between control points, the gross error can often be located within a short portion of the line, and that portion can then be rerun. In areas that have been subdivided by surveys of the General Land Office the traverse should be tied to the land lines as indicated by corners or by roads and fence lines. A comparison of distances on the traverse with the same distances as indicated by the plats of the General Land Office will often indicate the gross error of a traverse within a certain mile and sometimes within a less distance. Cumulative errors due to a stadia interval other than 100 should, as stated before, be provided against by testing the alidade to be used before field work is started. If there is an appreciable error in the interval a table should be prepared so that the error may be eliminated in plotting the distances. The adjustment of errors that can be eliminated by proper action is not advisable.

The errors in wheel and tape traverses will generally tend to make them too long. Foot traverse may be either too short or too long, the error depending on the accuracy of calibration and on the character of the area under survey. Plotting errors are usually all in one direction for any individual and result in a cumulative error. A tendency to plot too long or too short should be overcome as quickly as possible.

Cumulative errors may readily be adjusted by the method of similar triangles. Through the end points of the traverse (fig. 8) draw a straight line (AB). Measuring from one end, lay off on this line the distance (indicated by the control on the regular field sheet) which should be the end to end distance of the traverse. Call the end which does not coincide with the end of the traverse  $b$  or  $b'$  according to whether the distance laid off is respectively shorter or longer than the traverse. Take any convenient point (O) at one side of the traverse and at a sufficient distance away to avoid sharp angles of intersection with the line AB, and draw lines OA and OB. If the traverse is too long, draw a line from  $b$  parallel with the line OA and intersecting the line OB at point  $B'$ . Through point  $B'$  draw the line  $B'A'$  parallel to the line AB. Line  $A'B'$  gives the desired length of the traverse  $Ab$ , as parallel lines intercepting parallel lines are equal. From point O draw lines through road corners and the several angles of the traverse represented by points 1, 2, 3, etc. The end points of the adjusted traverse are represented by points  $A'$  and  $B'$ . To locate other points on the adjusted traverse, begin at either end  $A'$  or  $B'$  and through them draw  $A'1'$  parallel to  $A1$ ,  $B'5'$  parallel to  $B5$ ,  $5'4'$  parallel to  $5-4$ , etc. Point 2, any point on the traverse, may be located directly on the adjusted traverse by paralleling the direction of  $A2$  through point  $A'$  to the line  $O2$  the intersection  $2'$  being the desired point. Because of the successively similar triangles constructed, the same proportional reduction of distance is carried through for each segment as was applied to the end to end length of the traverse.

If the traverse is too short by any distance  $Bb'$  draw a line through point  $b'$  (fig. 8), parallel to the line OA to intersect line OB extended at point  $B''$  and proceed as before.  $A''$  and  $B''$  represent the ends and  $1''$ ,  $2''$ , etc., the intermediate points of the adjusted traverse.

In the actual use of the similar triangles method, it is not necessary to draw the whole lines from the point O. A segment of each line, through points of the traverse slightly longer than will be necessary for the enlargement or reduction, will suffice. By fastening tracing paper over the traverse, the construction lines and the adjustment can be made directly on the tracing paper and so be ready without further effort for transfer to the final field sheet. With only a moderately large error to be adjusted, it will be found that a careful adjustment of the intermediate road corners or principal points on the traverse line will suffice. The segments of traverse between such points can then be adjusted into place without appreciable error by shifting a tracing of the original traverse line.

The similar triangles method of enlargement or reduction is applicable to plats of other than traverse lines.

Adjustments of traverse lines should be made as field work progresses and not allowed to accumulate. Prompt adjustment of trav-

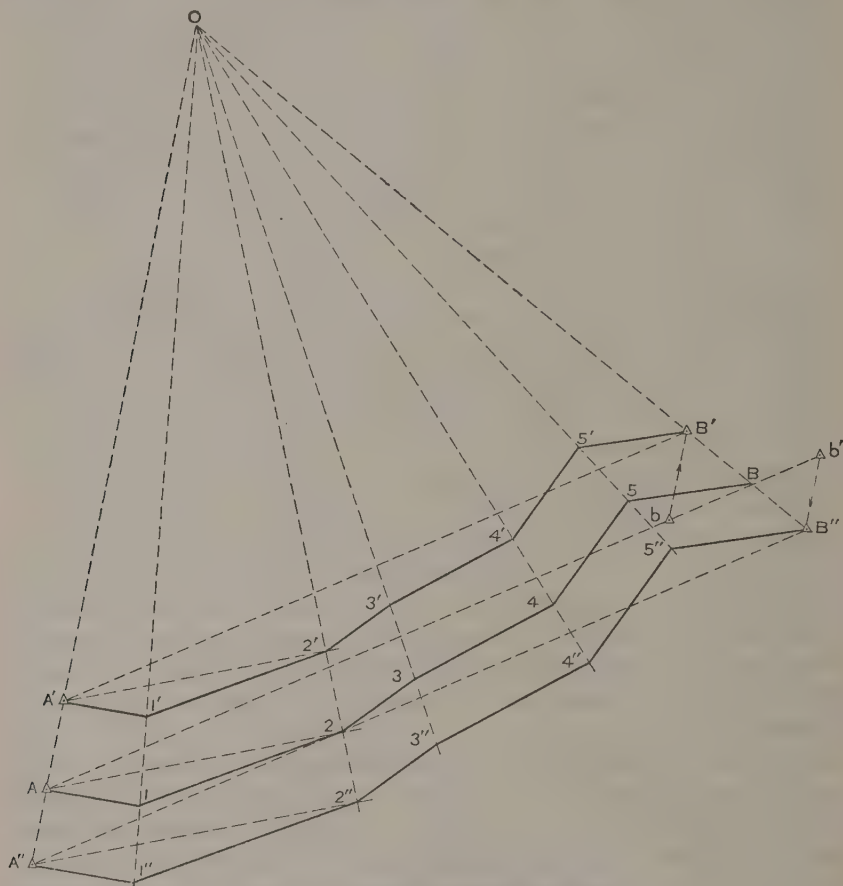


FIGURE 8.—Graphic adjustment of traverse

erses will enable the topographer to place a larger proportion of future traverse work in final position as it is run and thereby save avoidable transfer work with its consequent local adjustments.

### ANEROID BAROMETER

#### CHARACTER

*Field of use.*—In certain classes of work in different parts of the country the aneroid, properly supported by spirit-level and vertical-angle elevations, may be used to great advantage in the completion of topographic detail. In some regions, as in heavily timbered areas of moderate relief and especially where distances are determined by means of a cloth tape or braided rope (see "Tape traverse," p. 211), the aneroid affords the only practicable economical means of deter-

mining elevations. In order to obtain the best results from its use, however, the topographer should realize its limitations as a result of its delicate mechanism and its susceptibility to meteorologic influences.

*Construction.*—The aneroid barometer or the aneroid, as it is usually termed (pl. 13), consists essentially of a corrugated-metal box (vacuum chamber) which has been nearly exhausted of air and hermetically sealed. The corrugated metal is so thin and elastic that it expands and contracts with the slightest changes in atmospheric pressure. Inasmuch as there is a direct relation between elevation above sea level and atmospheric pressure it is only necessary to measure the amount of the movement of the top of the vacuum chamber in order to obtain a corresponding difference in elevation. The rise and fall of the corrugated top is greatly multiplied by transmission through a lever and chain to an index pointer moving over the scales as shown upon the face of the instrument. One scale (the inner) is graduated to indicate inches corresponding to inches of mercury in the tube of a mercurial barometer, and the other scale is graduated to indicate elevations in feet corresponding to the atmospheric pressure as measured in relative inches of mercury shown on the inner scale.

Each aneroid is constructed for use only to the limit of pressure for which its scales are graduated and for which nearly the complete circumference of the aneroid is used in order to give the largest graduations possible. Aneroids are kept in stock in the Geological Survey for elevations up to 3,000, 5,000, 6,000, 8,000, 10,000, 12,000, 16,000, and 20,000 feet, and no instrument should be used or transported beyond the elevation for which it is made.

*Scale relations.*—All Geological Survey aneroids have movable elevation scales. Aneroids of the "Tycos" type have elevation scales with a uniform spacing of the graduation intervals, but all other Geological Survey aneroids have elevation scales with slowly diminishing graduations. The zero or any graduation of the "Tycos" elevation scale may be correctly used for any elevation setting, but for all other types the scales are graduated for a zero elevation scale setting of 31 inches on the inner scale and give theoretically correct readings of differences in elevation only when the zero of the elevation scale is set at 31. The zero of the elevation scale is placed at 31 inches in order that all the readings on this scale may be positive, although the normal atmospheric pressure at sea level is nearer 30 inches than 31 inches.

#### TESTS

*Office tests.*—Each aneroid is examined in the Geological Survey instrument shop before it is issued. The aneroid is placed in a glass case, which is also connected with an air pump and standard mer-



curial barometer; the inch-scale readings of the two barometers are compared for several widely differing pressures, and, if found necessary, the aneroid is reset to its true reading by means of the screw in the back of the metal case. The mechanical parts of the transmission are likewise examined and are cleaned and repaired if such attention is needed.

*Field tests.*—The best field test for an aneroid is one that is made between points whose differences in elevation are known. A sensitive aneroid should show a small difference in reading between a horizontal and a vertical position of the face. This difference may amount to several scale divisions and is due to the extreme sensitiveness of the transmission and multiplying devices. If in further doubt as to whether the aneroid is working or not, exert a slight vertical pressure on the adjusting screw, using a hard point (not a pencil point), and if the needle responds by a movement equivalent to several scale divisions and moves back when the pressure is released the aneroid is probably working. The aneroid should not be opened nor should the screw in the back be turned by the topographer. Do not blow into the aneroid to test its sensitiveness, as the breath may rust the chain and spring.

#### USE

The aneroid may be used in several ways as described below, depending upon the method of setting the movable altitude scale of feet.

*Elevation differences.*—For the most accurate results the aneroid should not be used for reading elevations above sea level direct, but only for recording differences of elevation, much the same as a spirit level. For such use the zero of the elevation scale should be set at 31 inches, and this setting should be checked whenever the aneroid is read in order to guard against a slipping of the outer scale. Readings should be taken both on arrival at and departure from a station or any point where a stop of considerable length is made. Aneroid readings should be checked by comparison with previously determined elevations whenever opportunity is afforded, as well as at the beginning and end of each day's work. Notes should be kept on a form similar to that shown on page 217, for which a card can be obtained on requisition.

## Record of barometer readings

9.915

U. S. G. S.

Date	Place	Time	Barom. reading	Diff. elev. by barom.	Apparent elevation	Adjusted elevation
Sept. 1	B. M. 743	8 am	750			743
	Station 1	9 am	870	+120	863	870
	1	10 am	860			
	2	11 am	920	+60	923	932
	2	11.30 am	900			
	B. M. 857	12 m	820	-80	843	857

Record time and barometer reading on arrival and when leaving a station. Never change the barometer adjustment by means of the screw in back.

*Elevations direct.*—In using aneroids with elevation scales graduated into unequal parts (all Geological Survey aneroids except those of the "Tycos" type), where a scale error of 10 or 20 feet in 1,000 feet can be disregarded and especially where the range in elevation between resetting points is considerably less than 1,000 feet, scale settings to give very close elevation readings referred to sea level may be used as described below.

Set the zero of the elevation scale at 31 inches and note the scale reading at the occupied station, which in average weather will be many hundred feet in excess of the known elevation of the station. If this excess is less than 500 feet, use the zero of the elevation scale as the true zero and set the scale to read the known elevation. If, however, the excess is greater than 500 feet (in general it will be nearer 1,000 feet) add a fictitious 1,000 feet to the elevation of the known station and then set the elevation scale to indicate it. This device will more nearly bring into use those parts of the elevation scale that are intended for use and will tend to keep the zero of this scale near 31 inches, where in theory it should be at all times. The fleur-de-lis reading on the elevation scale must be recorded at each new setting of this scale and examined before each new reading for elevation as a check against possible slipping of the scale.

Example: Assume a station elevation of 1,020 feet above sea level and an aneroid reading of 1,850 feet for a scale setting of zero at 31 inches. Here the scale reading excess is 830 feet. Move the elevation scale to a 2,020-foot scale setting and thereafter assume that the 1,000-foot graduation is the zero. This expedient is easily kept in mind, and further unknown differences in elevation will be known within any possible error of 1,000 feet.

*Use of "Tycos" type.*—Aneroids of the "Tycos" type may be used for reading direct elevations (referred to sea level), inasmuch as the elevation scale is graduated into equal parts and may be moved until it indicates the known elevation at any point, such as the initial

station or subsequent known elevations reached in the course of mapping. In order to guard against a slipping of the elevation scale during the interval between the readings of the aneroid, a check reading of the fleur-de-lis on this scale should be recorded and examined before each reading for elevation.

*Reading the aneroid.*—The aneroid should always be held in the same position when it is read, and inasmuch as all shop tests and settings are made for a horizontal position, that position should invariably be used. The aneroid should be lightly tapped before each reading, using a pencil point or a finger nail. The aneroid should be tapped with the same force whenever it is read, and in the same place, preferably in the center of the face. A tap on the side or back of the instrument will often give a different reading.

Although the aneroid is compensated for changes in temperature of its metallic parts, sufficient time should be permitted to elapse for the parts to adjust themselves to any large differences in temperature between indoors and outdoors. Corrections for air temperature may be considered negligible in connection with Geological Survey determinations of differences in elevation by aneroid, as such corrections are appreciable only when large extremes of temperature and elevation are combined.

Whenever a station is occupied for a considerable length of time the usual record should be supplemented by an additional reading made just before departure, for a possible correction. After long ascents or descents the aneroid should be allowed a little extra time to settle. In general the aneroid responds less quickly to a descent than to an ascent.

*Care of the aneroid.*—The proper care and handling of the aneroid is the most important factor in its successful use. The aneroid is more delicate than a watch, and, because of the screw hole in the back, there is constant danger lest dirt or moisture gain access into interior transmission. (See pl. 13, *B*.) For these reasons the aneroid should be transported and handled with care and should be protected from all sudden jars and from rain, fog, and dust. It should be carried preferably in a closely fitting vest or small pocket secured by a string. This pocket should be periodically cleaned to remove dust. The aneroid should not be left loosely on a table or in a drawer with other things, but when not in use should be placed in its case and the case left where it will be least liable to jar or meddling. The aneroid should never be oiled. The transportation or shipment of aneroids across country whose elevation is beyond the limits of the aneroid range should be avoided.

*Weather influences.*—Inasmuch as changes in weather conditions are accompanied by considerable fluctuations in barometric pressure, topographers dependent upon the aneroid for elevations should be on the lookout for changes in local pressure, whether rapid or

gradual, and should make such allowances or corrections as may be necessary. Readings obtained during periods of most rapid or irregular increase or decrease in the pressure—for example, immediately before or after a thunderstorm—should usually be thrown out altogether. Although a steady barometer affords the best working condition, a slowly rising or falling barometer if recognized as such will in general afford a working condition practically as good.

### BALDWIN SOLAR CHART

#### OBJECT

The Baldwin solar chart (pl. 14) is designed to supply a means of obtaining true north, particularly for the orientation of the plane table in regions where the local conditions will not permit the usual determination by compass. When it is so turned that the proper pivot point on the arrow and the sun-time point on the local latitude ellipse are on a line parallel to the shadow cast by a plumb line upon a level table the arrow will point true north.

To use the chart some form of stylus or gnomon that will cast a good shadow must be provided. Either a sight alidade with an extra long sight vane or a carpenter's 2-foot rule that folds in 6-inch sections is suitable for the purpose.

#### EXPLANATION

The chart consists of elliptical lines indicating the sun's path for different latitudes from  $30^{\circ}$  to  $90^{\circ}$  N., at intervals of  $5^{\circ}$ , intersected by straight sun-time lines at 5-minute intervals. A separate chart is provided for use in latitudes  $0^{\circ}$  to  $30^{\circ}$ . The hour lines are heavy, and on them are shown intersections of elliptical lines for each degree of latitude. The respective hour figures are marked near the ends of the hour lines. The 30-minute and 15-minute lines are also solid but are lighter in weight and are marked with their proper number of minutes after the hour. The 5-minute intervals between the quarter hours are shown by dashed lines, the ends of the dashes being points on the elliptical lines for whole degrees of latitude, thus aiding in the interpolation of the line for the sun's path for any particular latitude. The points where the time lines intersect latitude lines are called sun-time points. Figure 1, Plate 14, represents the portion of the chart not completely shown in the section between 4.30 and 7.30 o'clock on the chart proper; it is an auxiliary diagram to aid in finding sun-time points between these hours. It is divided into segments, representing the time before and after 6 o'clock, on each of which the local latitude is to be interpolated between the radial lines and the sun time between the 5-minute lines shown. Points located on Figure 1 must be projected upon the local latitude ellipse in a direction at right angles to the sun-time lines of the



chart to locate the sun-time points for use. Guide lines are drawn on Figure 1 with extensions on the chart proper so that points may be projected by eye with sufficient accuracy.

Figure 2, Plate 14, is a diagram for finding the correct daily pivot points on the arrow. The positions of these points vary according to the sun's declination and the latitude of the observer. Morning and afternoon pivot points are equidistant from the middle point (*C*) of the arrow.

Figure 3, Plate 14, is a diagram by means of which local mean time may be converted into local apparent time. Below it are given directions regarding Figures 2 and 3 and the conversion of standard to local apparent time.

#### PREPARATION OF CHART FOR USE

It will be found convenient in surveying an area of small extent, say less than 20' in latitude, to emphasize, by drawing in pencil or colored ink on the chart, the curve of the middle latitude of the area, producing the curve so as to complete it to the 6 o'clock point. Draw on Figures 2 and 1 the lines for the same latitude, radiating from points marked "A" and "6," respectively. In Plate 14 such lines are drawn for latitude 43° N. Similar lines will be required for any material change in latitude.

A convenient device for fixing the daily positions of pivot points may be provided by sticking a narrow cardboard strip on the chart with one edge directly on the center line of the arrow, by means of shellac-alcohol adhesive, and marking on the strip in the form of a scale the positions of pivot points for the latitude of the locality for selected dates, so that the points for any intermediate dates can be found by interpolation. Cut away the portion of the strip representing all previous dates and use the corner of the strip at the point representing the current date as a stop against which the alidade is placed. A strip for each astronomical season should be provided, but only the one for the current season should be attached. Winter and spring strips should be placed on the outer side of the center line of the arrow and summer and fall strips should be placed on the inner side of the arrow, each in their proper turn for use.

When the chart is to be used on the west edge of the plane-table sheet it may be more convenient to turn the chart 180° from its regular position (that is, point the arrow south), so that the arrow will be directly over the projected meridian. The pivot points as found in normal position apply in this position also, but the relative position of pivot point and sun-time point will be reversed.

A tracing of the essential parts of the chart may be used instead of the chart itself. Those parts would consist of the elliptical curve for the latitude of the area (with its projection in the auxiliary diagram; see pl. 14, fig. 1), the time lines intersecting this curve, and

the north-south arrow. As the chart is designed to be used with local apparent time and to provide for daily change in declination, Figures 3 and 2 on the chart would necessarily be used for converting standard time to local apparent time and for fixing from day to day the pivot points.

In Figures 2 and 3, Plate 14, the day lines intersect the month's curve at date points corresponding with the noon values of declination and equation of time, respectively, for the year 1924 at Greenwich, England. For other years and places a date correction must be made as tabulated on the chart under Figure 3. Figure 2 is used to obtain pivot points on the arrow, two being required for each day. The north one is the a. m. pivot point and the south one the p. m. pivot point for any day falling in the half year between March 22 and September 21, inclusive (that is, when the position of the sun is north of the Equator); the relative positions are reversed during the other half of the year. When the arrow is pointing north the line from the a. m. pivot point to the sun-time point is directed toward the sun, and the line from the p. m. pivot point away from the sun.

Example: On July 20, 1925, find pivot point (*a*) and sun-time point (*b*) at 10 a. m., latitude  $43^{\circ}$  N., longitude  $85^{\circ} 40'$  W.

As indicated below Figure 3 of the chart, the time correction for  $85^{\circ} 40'$  west longitude is  $+\frac{1}{4}$  day ( $85\frac{2}{3}$  divided by 360). The correction for the period March to December in the year 1925 is  $-\frac{1}{4}$  day. The net correction (the algebraic sum of the two corrections) for use both in finding the equation of time and in finding the pivot point is zero. The day lines as drawn on the chart are therefore correct for the year and date given. Follow the 20th day line through Figure 2 of the chart to its intersection with the July curve. From this point of intersection follow an imaginary line perpendicular to the day lines to intersect the diagonal latitude line for  $43^{\circ}$ . From this intersection follow an imaginary line parallel to the day lines to the central white space of the arrow. That point on the arrow is a pivot point for the date given, and, as July 20 is between the spring and fall equinoxes and the sun is north of the Equator, it is the a. m. pivot point (*a*). At an equal distance on the other side of point *C* of the arrow will be the p. m. pivot point (*a'*) for the same day. If the date had been after the fall equinox and before the spring equinox, the first pivot point found would have been the p. m. pivot point. To find the sun-time point at 10 a. m. follow the hour line (10) to its intersection with the latitude curve  $43^{\circ}$ , as shown at point *b*. When the arrow points true north the line *ab* is in the direction cast by a vertical object upon a horizontal plane at the time and place given. When the plane table is level and is so turned that the shadow cast by a vertical object (the gnomon) falls along the line *ab* or parallel to it the arrow will point true north.

The sun-time point for 2.25 p. m. for the same date and place is shown at  $b'$  having been located on the latitude curve for  $43^\circ$  in the same manner as the point for 10 a. m. The line  $b'a'$  will be in the direction of a shadow cast by the gnomon at 2.25 p. m. when the plane table is leveled and turned so that the arrow of the chart points true north.

To find the sun-time point at 6.28 a. m. for the same latitude use the auxiliary diagram. (Fig. 1, pl. 14.) Follow the radial latitude line for  $43^\circ$  from the point 6 to a point three-fifths of the way from the 6.25 time line toward the 6.30 time line. Project this point horizontally to the curve for  $43^\circ$  latitude; the intersection ( $e$ ) is the sun time point for 6.28 o'clock. All sun-time points between the hours of 4.30 and 7.30 are found in the same manner.

For the year 1926, for the same place, month, and day as used in the examples given, the net correction to be applied in using Figures 3 and 2 of the chart would be  $-\frac{1}{4}$  day; recede along the month curve to a point corresponding to date point  $19\frac{3}{4}$  before proceeding to find the equation of time or the pivot points for the day. For a given latitude sun-time points for the same hours on any day are the same, but pivot points change daily.

Figure 3, Plate 14, is used to obtain the correction necessary to convert local mean time to local apparent (sun) time. This correction combined with the correction for longitude, gives the total correction to convert standard to sun time. To convert standard time to local mean time a correction of 1 minute must be made for each quarter of a degree of longitude east or west of the center of the time belt in which the work is being done, the correction to be added if east or subtracted if west. Standard-time meridians ordinarily are multiples of  $15^\circ$  of longitude east or west of Greenwich, England. Those crossing the United States proper are at longitude  $75^\circ$ ,  $90^\circ$ ,  $105^\circ$ , and  $120^\circ$  W. and are central meridians of the eastern, central, mountain, and Pacific standard-time belts, respectively. The Hawaiian standard-time meridian is  $157^\circ 30'$  W., and there are some other exceptions.

To convert local mean time to local apparent time, locate on Figure 3 of the chart a day line in exactly the same manner and applying the same corrections as in finding the pivot point by means Figure 2. Follow this day line, parallel to the day lines drawn, to its intersection with the proper month curve. This intersection is the date point for that particular day, and the corresponding time correction can then be read on the minute scale at the top of the figure.

Example 1: For July 20, 1925, longitude  $85^\circ 40'$  W. (same date and position as in previous examples) find the correction to convert standard time to local apparent time for use with the chart. Longitude  $85^\circ 40'$  W. is  $4\frac{1}{3}^\circ$  east of the center ( $90^\circ$ ) of the central time



belt. Applying the correction of 4 minutes for each degree of difference in longitude gives a correction of  $17\frac{1}{3}$  minutes, and, as the locality is east of the center of the time belt, the correction is to be added to standard time. The result is the mean time for the locality. To convert it to local apparent time for use with the chart, the equation of time as found from Figure 3 of the chart must be applied as a further correction. As the data used are the same as were used in finding the pivot points, the net correction to the day lines of Figure 3 is the same—that is, zero. On following the day line for the 20th to its intersection with the July curve, it is seen that this date point is opposite  $6\frac{1}{4}$  minutes to subtract on the minute scale. (Note that in pl. 14 day lines are drawn on fig. 3 only for each fifth day. Quarter-day corrections to day lines would therefore be expressed by twentieths of the space between the day lines shown.) The total correction to standard time to convert it to local apparent time (the sun time to be used with the chart) is the algebraic sum of the two corrections found—that is,  $+17\frac{1}{3} - 6\frac{1}{4}$ , or  $+11\frac{1}{12}$  minutes. In applying such a correction it should be approximated as closely as possible although that will probably be with more error than  $\frac{1}{12}$  minute. It will be found convenient to write on the chart, for daily reference, the constant corrections to be applied in a given locality. For the locality indicated in this example they would be “ $+17\frac{1}{3} \pm$  equation of time” and “No correction to date lines.”

Example 2: On September 12, 1925, at longitude  $96^{\circ} 30' W.$ , convert standard time to local apparent time. The correction on account of longitude will be  $-26$  minutes, and the correction for equation of time will be  $+3\frac{1}{2}$  minutes, a combined correction of  $22\frac{1}{2}$  minutes to subtract from standard time.

Other examples are given on the margin of the published chart.

Standard time can be obtained at most railroad stations or telegraph offices and at certain hours of the day by radio. The watch used should be set each day to apparent time by applying the constant correction for longitude and the daily correction for equation of time.

#### ORIENTATION OF PLANE TABLE

To orient the plane table by use of the chart, attach the chart to the plane-table sheet so that the arrow will be parallel to the line on the sheet representing the local meridian, with the point of the arrow in a northerly direction. The chart should have been prepared for use in the locality in which the work is to be done and the pivot points for the day plotted. Level the plane table at the station, select the sun-time point for the instant of observation, place the edge of the base of the gnomon so that it cuts the sun-time point and the proper a. m. or p. m. pivot point, and revolve the plane table until the shadow of the gnomon falls parallel to the edge of its base. The gnomon must be in a plane perpendicular to a level line at right angles to its base



edge that cuts the points on the chart. This may be accomplished by fixing a small bubble on the base of the gnomon at right angles to its edge or by utilizing the circular-plate bubble on the telescopic alidade and exerting just enough pressure on the plane table to center the bubble in the desired direction at the instant of observation. When the shadow falls as described, the arrow of the chart points true north; the plane table is oriented and should be clamped.

If a carpenter's 2-foot rule is used as a gnomon, open it so that its two end sections are together and approximately at right angles to the center two sections. Use the center two sections as the base and the end two sections as the upright part of the gnomon. The end two sections may be spread just enough to leave a narrow slot between them, and paper may be pasted on the upper side of the part used as a base, with the center line marked upon it. The plane table is then revolved until the sunlight falls through the slot upon the center line thus marked. Or the free ends of the rule may be kept together, and the plane table revolved until the slightly spreading shadow of the upright portion falls equally on the two sides of the base. The line from the morning pivot point to the sun-time point is directed toward the sun and the line from the afternoon pivot point away from the sun. To obtain best results it is necessary to use accurate time and to plumb the shadow plane carefully. A long gnomon gives more accurate results than a short one.

Example: To orient the plane table at 10 a. m. July 20, 1925, latitude  $43^{\circ}$  N., longitude  $85^{\circ} 40'$  W., place the edge of the base of the special gnomon or of a sight alidade (using the open-sight vane as a gnomon) on pivot point *a* and sun-time point *b*, with the shadow-casting end toward point *a*. Revolve the plane-table board until the shadow is bisected by a line parallel to the edge used, drawn from the center of the base of the gnomon; then the arrow points true north, and the board is oriented.

It must be remembered that an orientation using the chart as described is a true orientation. In order that lines sighted and drawn on the map shall be in their true direction, the line of sight of the alidade used must be parallel to its ruler edge. Any angular error between the line of sight and the ruler edge will result in a closing error for a traverse line that will be directly proportional to the distance of the closing point from the starting point. To test whether the line of sight and the ruler edge are parallel, stick two pins or needles against the ruler edge of the alidade and near its ends and sight then on a point about a thousand feet distant. If, without moving the alidade, its line of sight also cuts the same point the line of sight is parallel to the ruler edge. If the line of sight of a Burkland alidade is not parallel to its edge, it can be made so by shifting the sight vanes forward or backward from the old screw holes and reset-

ting them. In order to correct an appreciable error found in a telescopic alidade, place the arrow line of the chart parallel to the line joining the pins, then shift the alidade over the chart till the line of sight cuts the point sighted over the pins. Now draw a meridian line on the chart along the alidade edge. In use, the meridian so drawn must be placed parallel to the meridian of the field sheet. When the plane table is oriented the angular error in orientation will then equal and compensate the error due to the use of that particular alidade.

The length of sight on the field sheet should not exceed the distance on the chart between the sun-time point and the pivot point or the length of the shadow of the vertical gnomon in use. This will vary with the time of day and the season of the year.

#### ERRORS

The error in azimuth caused by errors in latitude, time, and level can be found graphically upon the chart for various conditions, but the error in azimuth due to error in time is most likely to be serious. At the pole an error in time of 4 minutes causes an error in azimuth of  $1^{\circ}$ . Elsewhere, if the sun time used is not over 3 minutes in error, the error in azimuth will usually be less than  $1^{\circ}$  before 10 a. m. and after 2 p. m. and will be least at low latitudes, but at low latitudes the error changes more rapidly near these hours than at high latitudes and at and near noon is greatest. On June 22 at latitude  $30^{\circ}$  N. an error of 3 minutes in time at noon will cause an error in azimuth of about  $6^{\circ}$ , but at 10 a. m. and 2 p. m. it will cause only  $0.5^{\circ}$ . At latitude  $40^{\circ}$  N. the error at noon will be less than  $2.5^{\circ}$ , whereas at 10 a. m. and 2 p. m. it will be about  $1^{\circ}$ . To obtain good results with the chart in plane-table traverse, the error in time should not exceed 3 minutes, and near noon in low latitudes it should not exceed 1 minute. Fast time increases the measured azimuth of a course, and as the error is greatest at noon a straight course run throughout one day would appear as a slight reversed curve, the morning curve to the right and the afternoon curve to the left.

#### TIME CORRECTION

Sun time can be found as described in the foregoing text. It can also be found directly from watch time (whether that is fast or slow) if the plane table can be reliably oriented each morning by known points by placing the alidade edge against the proper pivot point and toward the sun. The edge of the alidade will then cut the true latitude curve at sun time, and the difference between that and watch time will show the correction to be applied.

## NAMES

### NAMES WITHIN THE MAP

*Name sheets.*—All names that are thought to be appropriate for the final map should be assembled on sheets of tracing paper or linen and registered over each plane-table sheet. Name sheets must be kept current and preferably should be combined into two tracings for the north and south halves of the quadrangle map. The importance of a complete and authentic record of feature names is so great that nothing should be left for memory. All necessary notes should be made and all names recorded as soon as they are obtained.

*Authority for names.*—The topographer should utilize local opportunities for obtaining the correct names of all features shown on the map and not depend upon correspondence on this subject after his return to the office. The general policy should be to conform to local usage, but at least two independent authorities for each name and spelling should be obtained; and in case of differences in usage, spelling, or application, a definite effort must be made to obtain all pertinent facts, so that a just decision may be reached in the field or made the basis for further reference.

*New names.*—In unsettled or sparsely settled regions it may be found desirable to give names to the larger land and water features as a means of reference. As such names, by Executive order of January 23, 1906, must be referred to the United States Geographic Board for consideration and approval before publication, they should be submitted by party chiefs, through their division engineer, for action by the board before being used. Requests for consideration of new names should be accompanied by full information as to their appropriateness. The selection of new names should not be a mere matter of whim but should be made with due consideration of their geographic value and significance.

*Names to be shown.*—The map should show names of the following features:

Cities, towns, villages, and other settlements, including all country post offices and railroad stations. Where the name of a railroad station differs from that of the corresponding post office, both names should be shown, the one most widely known being given the greater prominence and the other being followed by "P O" or "Sta" as the case may be.

Country schoolhouses.

Country churches, where used as locality names.

Isolated ranches constituting important landmarks in sparsely settled districts. Important public institutions, such as universities, colleges, and State hospitals.

Railroads (steam or electric). In addition to the name of the railroad, it is desirable, as a rule, to give the name of the branch, line, or division, for complete office identification.

Highways, turnpikes, and boulevards.

Bridges, ferries, and fords.

Through trails.  
Principal steamboat routes on large lakes and rivers.  
Large canals, ditches, aqueducts, etc.  
Tunnels, dams, lakes, reservoirs, and other public works.  
Lighthouses, lightships, and life-saving stations.  
Parks and cemeteries, if scale will allow.  
Isolated mines, quarries, prospects, and oil wells.  
Isolated furnaces and smelters.  
Civil divisions.  
Reservations.  
Hydrographic features.  
Springs, wells, and tanks, especially in arid regions where these features are of vital importance.  
Relief features.

#### MARGINAL NAMES

The name sheet should be complete copy for all marginal lettering (pl. 15) that pertains especially to the map in hand. Data that are common to all sheets may be omitted.

The names of the topographers engaged in the mapping of the quadrangle must be listed in the margin of the name sheet. (See "Topographic authorship," p. 306.) It is not enough that the separate field sheets carry the names of the topographers responsible for their mapping.

Each name sheet must carry a diagram showing the area mapped by each topographer named in the author legend.

The date or dates of survey should be entered on the margin of the name sheet.

The contour interval used on the map and a statement of any changes in interval at any given contour should be recorded on the lower margin of the name sheet.

#### MAP BORDERS

*Adjoining unmapped areas.*—If any of the adjoining quadrangles have not been mapped, the field work should be carried across the border into such quadrangles far enough to obviate the possibility of later work not joining it. To insure this joining the over-edge topography should be carried to a road, stream, or ridge, if such a feature is near at hand, but if not the topography must be carried at least a quarter of an inch beyond the border on the field sheet and will seldom need to be carried more than half an inch. Failure to use good judgment in connection with this requirement may make it necessary to correct the copper plates where the borders affected are afterward joined by future work or to readjust future work slightly in order to avoid making corresponding changes on the plates.

*Joining previous work.*—Procure copies of such map borders covering adjoining areas as may be needed. (See "Map borders," p. 178, and "Border corrections," p. 302.) Should it appear in the progress



of field work that the older maps contain inaccuracies or are not up to date in the representation of culture, the new work shall be considered standard and the older work revised for such a distance over the border as may be necessary to effect a good joining. Should the older sheets prove so deficient in quality or so out of date in the representation of cultural features that a radical revision would be required to make them join the new work, the topographer must at once report the failure to join to the division engineer. Where new work practically though not exactly joins engraved or published work, expediency warrants a slight readjustment of the new work to fit the old.

*Datum of previous work.*—Where the horizontal datum upon which the map of an adjoining quadrangle has been published differs from that upon which the map of the new quadrangle is drawn, proper corrections to the projection lines must be made before comparing the joining of the topography on the two maps.

#### OTHER GENERAL FIELD INSTRUCTIONS

*Protection of field sheets.*—Field sheets should at all times be protected from injury or loss. When a field sheet is in use on the plane table it should so far as practicable be protected by heavy cover paper supplied for the purpose, in which a hole may be cut for each day's work.

*Identification of field sheets.*—Each separate piece of map manuscript, oversheet, or map material should be marked with the names of the State and quadrangle, the date, scale, contour interval, coordinates, authors' names, and other appropriate information. If more than one engineer works on a single sheet the areas covered by the several men should be indicated on the field sheet.

*Information tracing.*—The use of an information tracing is to be encouraged. On it should be assembled, over the map features for which added information is to be given, all data that can not be legibly penciled on the original. Such information is especially needed where the original has been rubbed and sharp penciling is difficult, where only the inked colors will clearly differentiate between closely spaced features, where detached contours might be mistaken for water features or the reverse, or where the desired treatment of the feature may be beyond the map scale and yet, because of the apparent need of showing it, the topographer wishes to leave its proper delineation for office determination.

*Separation of oversheet data.*—Separate tracings should be prepared and submitted for names (p. 226), woodland outlines (p. 255), road classification (p. 256), elevations (p. 241), and information, and no two or more of the classes of data above listed should be submitted on a single tracing. The placing of more than one class of data, as

listed above, on a single tracing will cause delay and confusion in the office operations and may be the cause of the inadvertent omission of essential data on the final sheets. The data on oversheet tracings should be kept current and not allowed to accumulate.

*Monthly field report.*—Monthly reports of field work (one copy to division chief, one to section chief, and one to chief topographic engineer) should be mailed not later than the first day of the succeeding month. The name of the sheet or project on which work has been done should be plainly indicated. A separate report should be submitted for each sheet or project. (See “Monthly field reports,” p. 272.)

*Field inking.*—No inking on final sheets should be done in the field unless authorized. Where an explanation is necessary, it should be placed on the information tracing.

### MAPPING OF CULTURAL FEATURES

*Definition.*—The cultural features are those features of the terrain that have been constructed by man, such as roads, buildings, and canals; those features designated by man but only partly constructed on the ground, such as boundary lines; and all names and legends.

*Features to be mapped.*—The following cultural features are to be shown on all topographic maps, either by the standard symbols shown in Plates 18–23 or by means of other conventions, which are described in the text.

Aqueducts, water and oil pipes.

Artificial depressions.

Bench marks.

Boundary monuments.

Bridges.

Buildings.

Canal locks.

Canals and ditches.

Cemeteries.

Civil boundaries.

Coke ovens.

County subdivisions.

Cuts and fills.

Dams.

Ferries.

Fords.

Furnaces and smelters.

Levees.

Life-saving stations.

Lighthouses, etc.

Location monuments.

Mine dumps.

Mines and quarries.

Mineral monuments.

Oil and gas wells.

Power-transmission lines.

Public-land lines.

Railroads.

Reservoirs.

Roads.

Steamboat routes.

Trails.

Transit-traverse stations.

Triangulation points.

Tunnels.

Useful elevations.

Wharves, etc.

*Roads.*—Roads should be penciled as final copy for inking according to the distinctions given below.

(a) Good public motor roads should be indicated by solid double parallel lines. Good motor roads are defined as those public roads

that may be used for automobile travel the greater part of the year and include all Government, State, county, or other public roads in such condition as to be available for such travel; all main or through roads in sparsely settled regions, regardless of condition; and all city streets and park drives open to the public.

(b) Poor public motor roads and private roads should be indicated by dashed double parallel lines. Poor motor roads are defined as those public roads which through disuse or neglect have become impassable for automobile travel or can not be traveled without risk to an automobile. Public roads that are passable for wagons but are not good for motor use should be classed as poor motor roads.

Public roads are defined as those built or maintained by the Federal Government, a State, or a subdivision thereof. Private roads include all neighborhood roads in rural districts (except those of sufficient length and importance to be regarded as through routes, as defined above); all lanes and stub roads to farms, country houses, or institutions; and cemetery drives and race tracks. Private roads are further defined as those roads built or maintained by private or neighborhood funds.

It should be especially noted that public roads should be shown by full or dashed lines according to their condition as good or poor for motor use, whereas private roads should be shown by the dashed symbol irrespective of condition.

Lumber or wood roads are in general to be omitted, but any principal through lumber roads that may be properly considered permanent cultural features are to be shown by the dashed symbol. In regions where winding roads are numerous and where there are few recognizable map features, the occasional plotting of the forks of a prominent lumber road is advisable if the two roads at the forks are of nearly equal prominence.

On the 1:192,000 scale no distinctions are to be made between roads of different classes. They are all to be drawn as solid double parallel lines.

*Field penciling of roads.*—Roads should be penciled with a uniform width which will reduce approximately to the width used by the engraver on the scale of publication. As few draftsmen can legibly ink on any scale a double-lined road with a space between the parallel lines less than that representing the space between two lines about 75 feet apart when plotted on a scale of 1:48,000, such a plotting may be taken as a standard for penciled road copy, unless the map scale or width of the road is such that a greater width can be plotted to scale. Pikes, drives, and boulevards materially wider than the limit above specified should be shown to scale. On maps drawn on large special scales all roads should be shown with their individual widths wherever they can be plotted.

*Buildings in general.*—The map must show all buildings of a permanent character, such as dwellings, public buildings, shops, factories, and other industrial establishments; it should be reliable not only as to their location but also as to their orientation—that is, the way each building is set with respect to the points of the compass.

Uninhabitable dwellings, whether farmhouses or miners' or lumbermen's cabins, are to be shown only where they constitute landmarks in regions of sparse culture.

The conventional black square is to be used for all buildings except those whose dimensions plotted to scale exceed the size of the symbol, which should be shown with their individual plan outlines. On large-scale maps all houses may have to be thus shown.

On the 1:192,000 scale only isolated houses in the country should be shown; those in towns and cities should be shown by a conventional symbol representing the solidly built up area.

Houses should not be shown as contiguous to the roads unless the distance that separates them from the edge of the right of way is so small that it can not be plotted on the scale of publication.

*House blocks.*—Detached houses in residence portions of cities, suburbs, and villages are to be shown separately wherever possible. If the scale does not permit individual houses to be shown indicate the group by a solid block, in accordance with the following specifications. Distances between houses are to be understood as from center to center, and length of street blocks as between building lines and not from center to center of streets.

1:48,000 scale field work for publication on 1:62,500. Houses, where evenly or nearly evenly distributed, should be blocked where the distance between them is less than 100 feet—for example, in a 500-foot street block six houses evenly distributed should be blocked, but five houses or less should be shown separately.

1:24,000 or 1:31,680 scale field work for publication on either scale. Houses should be blocked where the distance between them is less than 50 feet—for example, in a 500-foot street block 11 houses evenly distributed should be blocked, but 10 houses or less should be shown separately.

1:24,000 scale field work for publication on 1:62,500. Houses less than 100 feet apart should be blocked.

1:96,000 scale field work for publication on 1:125,000. Houses less than 200 feet apart should be blocked.

These specifications are set up in order to standardize the blocking of houses, to reduce the cost of field work in areas of heavy culture, and to afford specific copy for inking and for engraving. The decision as to the blocking of houses should be made in the field, and the data should be properly penciled on the field sheet.

*Business and residence blocks.*—Business and residence blocks should be distinguished by the width of the block, the residence blocks being made distinctly narrower than the business blocks.



*Churches and schoolhouses.*—Churches are to be distinguished by a cross and schoolhouses by a pennant, so attached to the house symbol as to point at right angles to the roadway. In centers of dense culture these distinctive symbols should be omitted. Buildings used both for schools and for religious services should bear the school symbol.

*Railroads.*—Railroads, whether operated by steam, electricity, gasoline, or other motive power and including all railroad lines listed in the Official Railway Guide should be shown by the broad-spaced symbol representing a railroad of any kind.

Electric trolley lines carrying passengers only and not issuing tickets with baggage-checking privileges should be shown by the close-spaced symbol.

Double tracks, railroad yards, spur tracks, and switches should be shown so far as the scale will permit. Separate railroad lines in juxtaposition and parallel tracks belonging to the same road should be differentiated by placing the crossties as shown on the symbol chart.

Tramways should be shown by the broad-spaced symbol. Aerial tramways should be shown by a broken line and with the name where there is space.

Railroads or electric trolley lines within a roadway should be shown by fine cross lines having the same spacing as those on the corresponding line outside of the road.

*Railroad surveys.*—A railroad alinement is made up of tangents and curves; most curves are compound, and many leave the tangent on an easement curve. Reversed curves usually have 200 feet or more of tangent between them. In traversing railroads these facts should be kept in mind, and the resulting plot should show a line free from abrupt deflections that are not found on the ground. Railroad azimuths should be well checked, by fore and back sight methods when necessary.

*Railroad crossings.*—Grade crossings should be shown by continuous railroad and road symbols; a railroad crossing over a road by a broken road symbol; and a road crossing over a railroad by a broken railroad symbol. Do not use the words "overhead" or "underhead."

*Railroad station buildings.*—A railroad station building is to be treated like other buildings, except where its symbol is carried conventionally across the track to indicate the location of a train stop that is not otherwise clearly indicated by the position of the station name or by the culture. The conventional station symbol should not be drawn across the track where there is no station building, and its use should generally be confined to small villages or cities.

*Bridges.*—Symbols should be used to show all road bridges across double-line streams and all road bridges across single-line streams

in sparsely settled regions or wherever the existence of the bridge is vital to the use of the road. Bridge ends should not be shown for viaducts over railroads, railroad yards, roads, or streams except on large-scale maps (1:24,000 or larger). Names of large viaducts, however, should be shown.

Drawbridges on roads and railroads should be shown by a separate symbol. Ordinary bridges and trestles on railroads are to be omitted. The bridge symbol should also be omitted wherever its presence would impair the legibility of the map.

The footbridge symbol should be used only where the bridge is of local importance—in general only where it is isolated and only where the scale permits. Footbridges should always be shown on large-scale maps.

*Ferries.*—Ferries are to be shown by symbol wherever the stream is wide enough to permit; where it is too narrow the word "Ferry" should be written. Names of ferries must be put on the map.

*Fords.*—The symbol for a road ford is similar to that used to represent a private road; the symbol for a trail ford is similar to that used for a fence of any kind. On large-scale special maps the route of the ford, if difficult to follow, should be shown accurately.

*Trails.*—Distinction should be made between good pack trails and poor pack or foot trails, the former being indicated by short heavy dashes and the latter by small dots. In mapping trails the topographer should consider their relative importance as a means of communication. Thus in mountain and desert regions, especially in the far West, where traveling is done largely by trail, he should take pains to map every trail in use, giving its name, if known; in the more densely populated districts, where railroads and wagon roads are plentiful, he should show only such trails as lead up mountains or through unimproved areas not readily accessible otherwise. A mere "way through" not regularly traveled does not constitute a trail.

*Steamboat routes.*—All steamboat routes on lakes and rivers over which a regular public service is maintained by ferries or passenger boats should be indicated by fine dashed lines and the words "Steamboat route."

*Canals and ditches.*—Canals, whether for navigation, irrigation, or drainage, should be shown by double-line symbol if their actual width can thus be indicated on the scale of publication; otherwise, by a single line. Abandoned trunk canals constituting prominent topographic features will be indicated by the long-dash symbol.

The mapping of irrigating ditches is to be restricted to the main feeders; laterals are not to be shown except on large-scale maps. On smaller scales only those ditches that constitute important landmarks in regions of sparse culture are to be indicated.

*Canal locks.*—The lock symbol should point upcurrent. The symbol showing both the upper and lower gates will be used only on scales large enough for their individual plotting.

*Aqueducts; water and oil pipes.*—Only the principal aqueducts and pipe lines should be mapped.

*Power-transmission lines.*—The alinement of high-voltage (100,000 volts or more) trunk power-transmission lines should be obtained in the course of the field survey and shown on the topographic maps. Sections of power-transmission lines within corporate limits and lateral distribution systems should be omitted. Trunk lines are in general built on private rights of way and in most parts of the country are placed on steel towers.

*Tunnels.*—Tunnels of all kinds, whether on railroads, roads, or canals, should be shown by the tunnel symbol; the route of the tunnel should be indicated by double broken lines.

*Dams.*—Permanent dams on streams, lakes, or reservoirs should be indicated by a heavy line. Where a wagon road follows the top of the dam, the road is to be shown in its correct place, the road line on the upstream side being thickened to represent the dam.

*Reservoirs.*—The shore line used to represent a reservoir should correspond to the normal full stage of the reservoir that is controlled by the dam. Where the penciled copy for reservoirs and the adjacent contouring are not clear, these details should be explained elsewhere by means of a large-scale sketch.

*Levees.*—Levees may be represented by the hachure symbol alone where the levee is too small to be shown to scale by the contours, but such representation should be confined to large-scale maps or to levees that are conspicuous or important features.

*Cuts and fills.*—The rule as to the use of hachure symbols for the representation of levees also applies to cuts and fills, but inasmuch as cuts and fills are in general sufficiently shown by the contouring and by the presence of roads, railroads, or waterways their further representation by hachures should be confined to special cases or scales.

*Artificial depressions.*—Artificial depressions, such as are found above railroad and highway fills, should be indicated by hachured contours. (See "Depressions," p. 251.)

*Mine dumps.*—The use of the hachured mine-dump symbol should be chiefly confined to large-scale special mining maps where all dumps are to be hachured. On standard-scale maps only those mine dumps should be hachured that for some reason constitute important topographic features not indicated by the contouring. It is impossible to frame a specific rule for general application, and instructions should be obtained for each map.



*Wharves, etc.*—Wharves, docks, jetties, breakwaters, and similar structures should be indicated by firm sharp lines and shown with such detail as the scale of the mapping permits.

*Lighthouses, etc.*—Lighthouses and light ships should be located on all maps, whatever the scale.

*Life-saving stations.*—Life-saving stations in general should be shown by the symbol followed by the letters "LSS," but life-saving stations of the Coast Guard should be shown by the same symbol followed by the letters "CG."

*Cemeteries.*—Cemeteries should be shown with their actual outlines, and the name should be used if it is well known and there is space, otherwise a cross within the outline or the letters "CEM" alongside. Small private cemeteries that are too small to plot to scale may be conventionally shown by a small square inclosing a cross but should be omitted unless they constitute landmarks in a thinly settled country.

*Mines and quarries.*—Relatively important commercial mines and quarries should be indicated by the pick and hammer symbol, which should be engraved. The commercial character of a mine may usually be judged by its possession of railway switches or docks to facilitate transportation or of permanent equipment. Lack of these would exclude from the engraved maps mines or pits worked only to supply neighborhood demands.

In sparsely settled regions, where there is little culture to be represented, isolated mines, quarries, and even prospects (sawbuck cross) that constitute landmarks and are widely known should be shown with their names, which should be engraved.

Mineral prospects exceeding 10 feet in depth, country coal banks or mines worked only for local supply, and abandoned mines should be plotted (inked in red) for the advance sheet only. The copy should clearly distinguish between mines that are to be inked in black for publication and those that are to be inked in red for the advance sheets only, and this distinction is usually most clearly indicated on the information tracing.

On special-scale mining maps all mining features including prospects may have to be engraved. It is for this purpose that the special mine symbols for shafts, tunnels, drifts, etc., are provided.

*Oil and gas wells.*—Producing oil and gas wells should be indicated and engraved. Where such wells are so abundant as to be practically indistinguishable, only the approximate outline of the pool (by dashed lines) is to be shown.

*Furnaces and smelters.*—No additional conventional sign is used to represent furnaces, and in many areas it will not be practicable or desirable to name them. In many sparsely settled regions, however,



the furnaces are the most important and persistent landmarks. They have well-recognized names, which cling to the localities even after the practical disappearance of the furnace itself. In such areas, therefore, it is desirable that the names be given, even if nothing remains but a ruined stack. The same rule applies to smelters, except that those located should be restricted to smelters in active or prospective operation.

*Coke ovens.*—Only coke ovens connected with mines in operation are to be shown on the engraved maps.

*Civil boundaries.*—All civil boundaries, whether national, State, county, district, civil township, reservation (national or State parks, forests, monuments, bird and game preserves, Indian, military, or lighthouse), land grants, corporations (city, town, or borough), parks, and cemeteries, are to be shown on the map by their respective symbols. Special effort should be made by field parties to locate such boundaries with accuracy and directly from triangulation points or transit-traverse lines if practicable.

Necessary descriptions, survey notes, and plats of all lines of importance should be consulted or procured. Data on national or State reservation boundaries should be obtained at or through the Washington office prior to the beginning of the field work. Data on minor civil subdivisions can best be procured locally, while the survey is in progress. Many boundaries are obscured or obliterated by natural causes or artificial works; some were indifferently marked to begin with; others have lost some or all of their marks. Information from local settlers may often prove of value and save time and effort in the search for such obliterated lines. The topographer will do well to avail himself of such information; at the same time he should bear in mind that the word of a resident is not to be taken as authoritative, but merely as supplementing information from official sources.

Where lines are found incorrect in azimuth and distance as the result of field errors, it is a fundamental principle that the line marked on the ground is the *de facto* boundary and is to be shown on the map in its actual position, regardless of what the statute calls for. This principle may necessitate the accurate locating of a number of monuments, so that each error in the alinement may be designated at the particular spot at which it exists.

Some civil boundaries are defined by statute to follow natural boundaries, such as streams or divides between drainage basins. Those following large rivers should be given special attention, as they may be variously defined as following the middle of the stream, its main current, or one of the banks. (For descriptions of national and State boundaries see Bulletin 689; see also references listed separately by names of boundaries, pp. 322–328.)

*Boundary monuments.*—All monuments on national, State, and national park boundaries must be located in the field and represented on the map with the side of the open square oriented with the direction of the boundary line and with its designating number alongside. On other boundaries monuments occupying controlling positions, such as corners or important crossings, should be located.

*County subdivisions.*—The policy of the Geological Survey is to show only such county subdivisions on its topographic maps as appear reasonably permanent in character and in location, and to exclude from its maps any representation of county subdivisions that are subject to frequent changes at county elections. Topographic engineers should therefore become familiar with the legal system of county subdivision in the States in which they are working and should seek local advice and facts upon which to base appropriate action or a request for instructions.

In general, counties are divided into smaller units that bear different designations in different States or even different designations in different counties in the same State. In the States organized from the public domain and surveyed under the public-land system the so-called congressional township has usually been taken as the organization unit. In New England and in parts of the country affected by New England migration are found town units, in which are vested many of the powers that in the South and in the newly settled West pertain to the county. Some counties in Maine, New Hampshire, and Vermont, in addition to the towns and cities that are the only regular subdivisions, have partly organized or unorganized territory laid off by the States as plantations, gores, grants, purchases, locations, and islands.

The following summary, taken from Census reports, gives the names of the primary divisions of the county in the several States and outlying Territories:

Alabama.....	Election precincts.
Alaska.....	Recorders' districts.
Arizona.....	Election precincts.
Arkansas.....	Townships.
California.....	Judicial townships.
Colorado.....	Election precincts.
Connecticut.....	Towns.
Delaware.....	Representative districts.
District of Columbia.....	None.
Florida.....	Election precincts.
Georgia.....	Militia districts.
Hawaii.....	Election districts.
Idaho.....	Election precincts.
Illinois.....	Townships and election precincts.
Indiana.....	Townships.
Iowa.....	Townships.

Kansas.....	Townships.
Kentucky.....	Magisterial districts.
Louisiana.....	Police jury wards.
Maine.....	Towns and cities.
Maryland.....	Election districts.
Massachusetts.....	Towns and cities.
Michigan.....	Townships.
Minnesota.....	Civil townships and townships and ranges.
Mississippi.....	Beats.
Missouri.....	Townships.
Montana.....	School districts, townships, and election precincts.
Nebraska.....	Townships and election precincts.
Nevada.....	Townships and election precincts.
New Hampshire.....	Towns and cities.
New Jersey.....	Townships.
New Mexico.....	Election precincts.
New York.....	Towns and cities.
North Carolina.....	Townships.
North Dakota.....	Civil townships, election precincts, school townships, and school districts.
Ohio.....	Townships.
Oklahoma.....	Townships.
Oregon.....	Election precincts.
Pennsylvania.....	Townships, cities, and boroughs.
Porto Rico.....	Barrios.
Rhode Island.....	Towns and cities.
South Carolina.....	Townships.
South Dakota.....	Civil townships, election precincts, school townships, and school districts.
Tennessee.....	Civil districts.
Texas.....	Commissioners' precincts and justices' pre- cincts.
Utah.....	Election precincts.
Vermont.....	Towns and cities.
Virginia.....	Magisterial districts.
Washington.....	Election precincts.
West Virginia.....	Magisterial districts.
Wisconsin.....	Towns.
Wyoming.....	Election districts and election precincts.

*Public-land lines.*—In the so-called public-land States all lands that have at any time been subdivided or “sectionized” by the General Land Office must be shown on the topographic maps of the Geological Survey by indicating such township and section lines as have been run and have been approved by the Land Office and are not under suspension, and by showing by a distinctive symbol such public-land survey corners as have been found in the course of the topographic survey, after a reasonably diligent search and through inquiry. The relative strength or weakness of the land net will be indicated by the proportion of found to unfound corners. All corners are theoretically marked on the ground, but in practice many are

difficult or even impossible to find. (For a description of the public-land survey system see pp. 368-376.)

In settled country, where land lines often become property lines, there are section-line roads and fences, and there the construction of a public-land survey net is usually simple. But in unsettled country or in settled areas where the roads or fences seldom conform to section lines it is necessary to find on the ground and locate on the map enough section corners to enable the engineer to construct a land net built up from the Land Office plats and notes and tied to the section corners found. Such a land net when superimposed upon a topographic map will indicate the true, theoretical, or approximate location of each land line and corner with respect to the topography, according as corners are found or are only located from the plats and notes.

The land net should be completed in the field and compared with published maps of adjoining areas, and not left for office adjustment. If the Land Office plats can not be reconciled with the topography, even though a few isolated corners may be found, the section or township lines or both may be omitted, and a note added to the map to this effect. The note will be engraved and will list the omitted townships. (See "Land lines and topography," p. 307.)

*Search for public-land corners.*—The time warranted in search for obscure corners will be generally determined by the probable regularity or irregularity of the net and the proximity of corners already found. The less local information is at hand obviously the greater the necessity for pioneer hunting for the needed land ties. Diligent search must be made on the ground for all corners believed to exist near the line of survey. Hence the best judgment must be used before giving up the search.

In a region where there are few roads on section lines assistance in finding corners may be had by using an oversheet of tracing paper or linen upon which has been laid out to field scale either a single typical township or an entire land net covering the area to be mapped, built up in advance from the Land Office plats and notes. Such is a tracing, placed in position over a field sheet as soon as the first land corner has been plotted, will indicate graphically the theoretical location of all other corners; and as more corners are found the further placements of the tracing become more serviceable as a guide.

The topographer should be thoroughly conversant with the system of rectangular land surveys and the intricacies peculiar to it. Acquaintance with the standard monuments used for the several classes of land corners, their marks, and their bearing trees, as well as with the manner in which blazes on trees become overgrown with bark, will prove most useful both in searching for corners and in



determining their authenticity where this is in doubt. (For a discussion of the public-land survey system see p. 368.)

*Location and mineral monuments.*—Monuments erected as permanent reference marks for the location of mineral and other claims (often designated as USLM's or USMM's) must be located with the same accuracy as land-survey corners and if practicable by plane-table triangulation and should be shown on engraved maps with their designating numbers.

Authority is vested in the United States mineral surveyors to establish "mineral monuments" where no land-survey corners exist in the immediate vicinity of claims and to number them serially in each State. A former practice was to establish so called "location monuments" in each separate mining district, numbered serially in each district, and those already established are still so designated. A careful distinction must be made between the two systems, and the numbers of the monuments must be obtained; the abbreviations used are, for example, "USLM 2," "USMM 237."

*Triangulation points and transit-traverse stations.*—The triangulation points and transit-traverse stations to which the topographic mapping of the quadrangle has been tied must be accurately indicated on the topographic maps with the open triangle and dot symbol, which will be engraved. Wherever practicable the elevation of each of these points and stations should be determined by levels, stadia, or vertical angles and be stamped on the tablet or post that constitutes the permanent mark. If vertical angles have been used, the letters "V A" are to be stamped below the elevation figures.

*Level bench marks.*—All permanent and supplementary bench marks must be diligently looked for and accurately located on the field sheets with a view toward inking them on the final office drawings. Topographic field parties should not rely upon finding bench marks by search alone but must locate them systematically with the aid of printed or typewritten descriptions or of notes furnished by the level parties. Bench marks should not be shown where in areas of heavy culture, their representation on the map would be illegible.

Indicate the exact position of the bench mark with a small needle hole and right-angle cross in order that its true relation to the side of the road, cross roads, railroad, or house may be evident. Indicate all bench marks, both permanent and supplementary on the field name sheets, with letters "BM" for the permanent bench marks and with elevations for all.

*Vertical-angle bench marks.*—Where it is not expedient to run lines of third-order levels into or across mountain areas provision is made for the establishment of vertical-angle bench marks and for their permanent marking on the ground. Such bench marks must be well tied to one or more level bench marks by a system of well-checked

reciprocal vertical angles from plane-table stations within the main plane-table control triangulation net of the quadrangle. Vertical-angle bench marks should be located at triangulation points or other conspicuous summits so far as practicable and should be kept away from roads or other routes of travel. Where, however, a vertical-angle bench mark is established near a road it should be designated "VABM" in order that there may be no doubt of its character, but on summits the designation will be the same as level bench marks, "BM."

*Reporting bench marks not found.*—Bench marks must be found or reported as not found. Therefore, report promptly to the chief topographic engineer any bench marks (permanent or supplementary) that have been looked for and either not found or found to have been disturbed, in order that the office records and the level-bulletin manuscripts can be corrected. Also indicate them on the field name sheet as not found.

*Control points adjacent to cultural features.*—In plotting cultural features adjacent to horizontal-control points or in plotting bench marks adjacent to cultural features the copy for inking should be accurate and clear as to the relation between the culture and the control shown.

*Useful elevations.*—In addition to the permanent and supplementary bench marks, reliable elevations that have been determined by means of leveling or stadia at road corners, summits of mountains and hills, water surfaces of lakes, ponds, and wide rivers, prominent high points in roads, section corners, boundary monuments, and other appropriate places should be penciled on the field sheets. In selecting these elevations for the maps, the topographic engineer should bear in mind that it is the policy of the Geological Survey to publish, either on the advance sheets or on the engraved maps, only such elevations as have a definite working value; therefore only those elevations should be finally penciled on the field sheets that can be identified on the ground and on the map both in elevation and in location.

The distribution of useful elevations on the final field sheets should be based on a spacing of about half a mile apart for maps plotted on a field scale of 1 : 48,000 and about 1 mile apart for a field scale of 1 : 96,000, and in proportion for other field scales. Shorter spacings should be used, however, wherever features of unusual importance or large differences in elevation are involved; and under certain conditions, when specially authorized, even more elevations may be indicated.

*Elevation tracing.*—If the field sheets are drawn on a scale of 1 : 31,680 or on a larger scale, all elevation data must be assembled on an oversheet tracing in the field, as the small elevation figures that have been placed on the field sheets themselves are ever in danger of being

erased or so obscured as to be illegible. The point of application for the elevation given should be clearly indicated on the tracing.

### MAPPING OF DRAINAGE FEATURES

*Drainage features defined.*—The drainage features of the terrain are those features representing water, such as flowing streams, lakes, and shore lines, and those features indicating some degree of wetness, such as intermittent streams, marsh, and glaciers.

*Features to be mapped.*—The drainage features to be shown on all topographic maps, by standard symbols (see pls. 18–23) or by means of other conventions as described in the text are listed below.

Glaciers.	Sand.
Lakes.	Springs.
Marshes.	Streams.
Shore lines.	Wells and water tanks.

*Tidal shore lines.*—On all topographic maps of the Geological Survey the line of mean high tide is considered to be the shore line. In determining the margin of mean high water, exclude the highest (semimonthly) tides and take the average of the usual high tides as generally marked by the limits of vegetation.

*Use of Coast and Geodetic Survey charts.*—The fullest practicable use should be made of the charts of the Coast and Geodetic Survey in mapping coastal areas. The charts should be photographed to the scale of the field work, and where they represent recent work on a scale as large as Geological Survey field work, or larger, the shore-line data should be transferred to the field sheets. The data taken from charts must be instrumentally checked to insure their correct adjustment and tie to the Geological Survey topography, and afterwards they must be examined in detail for possible changes.

*Marshes in general.*—Both fresh and salt marshes should be represented by the symbol for marsh in general, and no distinction should be made between them in field work. Marsh or swamp land is defined as land that is not suitable for cultivation without first being drained. The outlines of marsh areas should be indicated in dashed lines and inked but will be engraved only under certain conditions, which are described on page 291.

Marshes on low coasts are as a rule traversed by a network of tidal channels. Unlike the rills in mud flats, these channels are fairly permanent in location, and those that exist at mean high tide should be mapped individually so far as the scale permits.

*Submerged marsh.*—Marsh lands that are partly submerged for many months each year are to be differentiated from ordinary marshes and represented by a symbol combining water and marsh tufts. The inking copy should be clearly indicated.



*Wooded marsh.*—No symbol has been provided for wooded marsh other than that offered by the green woodland overprint over the marsh symbol. Areas of wooded marsh should therefore be included in the areas shown on the woodland tracing, but with a note alongside so that they will not be inadvertently stricken out in the office.

*River shore lines.*—Broad rivers offer a perplexing problem to the topographer, as, owing to their periodic fluctuations, their width often varies considerably with their stage. The general rule is that the width shown should correspond to the normal stage. The normal stage may be defined as that water level which remains nearly stationary for the greater part of the year, and therefore it excludes all stages of relatively short duration resulting from floods, whether periodical or out of season, and all low-water stages resulting from exceptional run-off. The normal stage will, in general, be found to exist for about 9 to 11 months for most streams. If any other stage of water other than the normal has been mapped by other Government agencies instructions should be sought as to the availability and best use of the material. The elevation of the plotted shore line should be indicated at short intervals, and the figures of elevation should be placed in the space indicating water surface where they can be made readable.

In areas where the flow of rivers, though active for brief periods, dwindles or ceases altogether for many months the normal or prevailing stage is very low. Thus, rivers like the Platte are normally braided streams and should be represented as such on the map. Many rivers in the desert regions are most of the time nothing more than broad sandy washes and should be shown by strips of sanding.

*River banks.*—If the contour interval is too large to permit the delineation of river banks by contour lines, hachures may be used, a single row being sufficient.

*Natural lakes.*—The shore line used to represent a natural lake or pond should be that corresponding to a normal stage of water and not necessarily the shore line that is found at the time of the survey, which may be during periods of flood or extreme drought. An effort should be made to ascertain the shore line of the normal stage, as usually marked by a line of permanent land vegetation. The shore line used to represent a large lake that is subject to a gradual rise or fall over long periods should be that found at the date of survey. This date should be indicated on the water surface and be inked, and it will usually be engraved.

*Artificial lakes.*—The shore line of an artificial lake should be the line that represents the water surface at the full normal stage of the lake, as controlled by the dam.

*Island shore lines.*—The shore line that is to be mapped for an island must be that corresponding to the stage of water used for the



adjoining mainland shore line. Islands exposed only at a stage of water below that used for the mainland shore line should therefore not be mapped.

*Drainage classification.*—The field sheets should clearly classify all streams as perennial or intermittent; this classification is defined below, and as it can not be accurately made in the office it must be completely made in the field.

*Perennial streams.*—A perennial stream is one that flows throughout the year. It should be represented on the field sheets by a solid penciled line, firm enough to avoid confusion with the light penciled drainage that is drawn simply as a basis for contour construction. The topographer should show all perennial streams and leave for office decision the possible omission of any that may be considered not within the publication scale. Although the map should not be overburdened with insignificant rills and forks, such as abound in well-watered countries, the perennial drainage symbol should be penciled in all cases of doubt. As the purpose of this symbol is to show where running water may be found, it should be indicated on the field sheets only where the perennial character of the stream is reasonably established; and to this end occasional inquiry should be made to supplement field observations.

*Intermittent streams.*—An intermittent stream is one that is dry for a considerable time each year, say for three months or longer. It should be represented on the field sheets by a firm penciling of the dash and three dot symbol. In regions where both perennial and intermittent streams abound the penciling should be complete and clearly distinct as to each kind, but if the proportion or amount of intermittent drainage is so large that the field drafting of the dash and three dot symbol becomes burdensome the copy can be made clear for inking by means of an overtracing (information sheet) showing only the perennial streams with a statement that all other streams are intermittent.

*Double-lined streams.*—No stream should be double lined unless its actual width can thus be shown on the scale of publication without need of exaggeration.

*Drainage lines as contour control.*—All drainage lines should be lightly penciled in on the field sheets, as they constitute a controlling element of all normal erosion topography and serve as a natural skeleton for the construction of the contours. Indeed, the systematic tracing out of the drainage net can not be too strongly recommended; the earlier the topographer begins to cultivate the habit the more successful he is likely to be in his work. Even in volcanic, sand-dune, or glaciated areas, where the topographic features have been shaped by agents other than running water, the drainage lines will often be invaluable to the topographer in making clear the real nature of

slopes and irregular surfaces that are in themselves deceptive to the eye.

*Disappearing streams.*—Many streams in limestone regions abruptly sink into caverns and continue their courses for long distances through subterranean channels. Special care should be given to the mapping of streams of this type. The points of disappearance and reappearance should be accurately located.

*Springs.*—The importance of representing springs on a map is dependent on their relative usefulness as a part of the water resources of the region. Thus springs should be shown on maps of desert regions, where they are literally of vital importance and their omission or erroneous location may have the gravest consequences to those dependent on the map. In such regions the name by which each spring is known should be indicated. Intermittent, alkali, or undrinkable springs should be so designated on the map. Springs should usually be omitted from maps of well-watered regions, but even there conspicuous springs may be shown by symbol and by name if locally recognized. The inking copy must be clear, and if necessary the presence of springs should be noted on the information sheet.

*Wells and water tanks.*—The importance of wells and tanks, like that of springs, depends entirely on their relative usefulness as a part of the water resources of the region. In semiarid regions both wells and tanks must be shown. Wells, if artesian, should be so designated. The presence of wells and tanks should be shown on the information sheet if the field-sheet copy is not clear.

*Intermittent and dry lakes.*—Shallow lakes and ponds that are dry for many months each year are typical of some regions, and all those not too small for the scale must be shown. Dry salt lakes and alkali flats, although not intermittent in the usual sense, are so closely related to intermittent lakes in appearance and formation that they should be shown by the symbol for intermittent lakes. Both types should therefore be shown by a dashed outline with the surface indicated by hatching.

*Glaciers.*—The area of each glacier should be outlined by a dotted line, and its surface should be contoured (blue on the final map) with the same contour interval as that used for adjoining land surface and with the same degree of accuracy.

## MAPPING OF RELIEF FEATURES

### CONTOUR LINES

The relief on all topographic maps is expressed by contour lines. (See "Relief expression," p. 164.)

*One contour interval.*—The contour interval that should be used on any map will be stated in the field instructions that are issued to

topographic engineers for each separate field assignment. If, in the course of field work the use of a different interval appears to be advisable, prompt recommendation should be sent to the division engineer.

*Two contour intervals.*—Where the lower or valley parts of a quadrangle are to be contoured with a smaller contour interval than is to be used in the higher or hill parts of the quadrangle the change from one contour interval to the other should be made on one of the emphasized contours. For example, in changing from a 5-foot to a 25-foot interval the change should be made on one of the 100-foot contours. Where, however, the border line between the valleys and the foothills represents a line that is rapidly rising or falling the emphasized contour on which the interval is changed should itself be correspondingly changed, in order to give the greatest possible expression with the small contour interval to the flatter country and to avoid the unnecessary use of a small contour interval in the bolder country.

Where intermediate contours are needed to show detailed relief in certain small parts of a quadrangle, as in small valleys or flats, such contours may be added in dashed lines without interfering with the sequence of the regular heavy and light contours on the map.

#### CONTOURING METHODS

Contours may be mapped from plane-table set-ups that are made directly over or adjacent to the country that is to be mapped, as along a traversed road; or from a table that is kept stationary while it is circled by one or more moving rods; or from plane-table stations that overlook the distant country that is to be contoured. These three methods of contouring are described below.

*Contouring from a traverse line.*—In regions where the principal control is obtained by different kinds of traverse (which in general are extended along public highways), the usual procedure is first to plot the contour crossings and other contours on or near the traversed road or other traverse line and then to extend the contouring out on both sides of the traverse line as far as good visibility and locally established control warrants. Where the visibility from a traverse line is poor all necessary advantage should be taken of such relatively good view places as are passed; and if good sketching points are noted off the line but near it, such points should be occupied as the work progresses. Contouring from a traverse line may also be advantageously supplemented by having the rod held occasionally at salient points in the topography off the line.

When all sides of a road circuit or other large traverse circuit have been thus traversed and mapped, traverses should be extended into or across the unmapped interiors, giving sufficient traverse control to



enable the topographer to complete the mapping. Such interior traverses may be run across open country or along ridges or streams, or the topographer may occupy favorable interior viewpoints with the plane table and resect from previous traverse locations in order to obtain a plane-table location.

*Contouring from radial rod readings.*—In open country of low relief where little contouring can be done from single plane-table set-ups one or two rodmen and a recorder can be advantageously used. Where two rodmen are employed each holds a rod on different sides of the plane table and at the salient points in the topography, and each rodman advances in the direction of the proposed mapping. As soon as the sights become too long or are about to be obscured both rodmen should hold their stations, and these points should be used as turning points in the line and the mean of the two readings used in determining the elevation of the new plane-table station that is made beyond the points held by the two rodmen. The rodmen then advance as before. Plane-table locations may be obtained as in "Contouring from a traverse line" (above) or as in "Contouring from stations" (below).

To use this method to advantage the topographer should employ such signals as may be found necessary between the table and the rod and between rods and should fully instruct the rodmen in their duties, as much depends upon their activity and resourcefulness. The readings that result from the successive rod sights may be plotted as fast as they are taken, or they may be allowed to accumulate and be plotted after the series has been completed, as local conditions may dictate.

*Contouring from station.*—In open country of bold relief, where all the features are plainly visible, contours can be best delineated from plane-table stations overlooking the country to be contoured, without the running of a traverse line or the use of a rod. The method of contouring from plane-table stations involves the use of plane-table triangulation (p. 197) and the three-point method (p. 202). Woodland country as well as open country may be contoured from stations provided a sufficient number of outlooks can be found from which a satisfactory view and a good determination of position can be obtained. In the construction of contours from a station the location and use of drainage lines is important. (See "Drainage lines as contour control," p. 244.)

Contouring from a station is dependent upon supplemental control that is obtained by the location on the plane-table sheet by intersection methods of many of the salient points on the surface that is to be contoured; and for this reason little sketching can be done from the first station other than that of form lines, which are afterwards converted into placed contour lines. (See "Form lines,"



p. 249.) In planning the order in which plane-table stations should be made, careful consideration must be given to the need for the sighting of many points ahead, so that a sufficient number of such sights may be intersected from subsequent stations and used as a basis for contour construction. Vertical angles may be taken to the points when they are first sighted, or after the points that have been sighted have been intersected, or at both times, as circumstances may warrant, but in either procedure the elevations must be computed and the contours placed on the map as soon as the intersections are obtained.

The elevation of plane-table stations must be determined from a carefully executed series of reciprocal vertical angles taken between the principal stations in the quadrangle, and at least one station must be directly connected with a level bench mark by means of reciprocal vertical angles measured under different conditions.

*Contour skeleton outline.*—Before mapping the contours that are to represent a distant relief feature a skeleton outline of that feature should be prepared, and on the degree with which this is adequately accomplished depends much of the accuracy, speed, and ease with which the contours themselves are placed on the map. Although it is true that lacking such an outline an experienced topographer will make a more faithful contour sketch than one less experienced, it is equally true that the best and most experienced topographers make a suitable skeleton outline of the drainage and ridge lines before attempting the construction of the contour lines themselves.

The landscape that is to be contoured should be first divided into its separate features or unit masses, such as mountains, hills, and spurs, and then, after sufficient control has been established through intersection methods, each feature thus segregated should have its natural drainage-line boundaries sketched in, tangents drawn to salient points as well as located points being used as control for the placing of the drainage lines. Similarly, ridge and crest lines may be outlined. It is best, as a general rule, to use convex forms such as spurs and lateral ridges as unit masses, the intermediate drainage lines being used as boundaries. (See also "Drainage lines as contour control," p. 244.)

In determining elevations based on vertical angles it is well to remember that large angles must be supplemented with accurate measurements of distance but that small angles based on measurements of distance that are approximate only will yield useful elevations for contour work.

Each separate unit mass as above described should be completely contoured, so far as control and visibility permits, before the contouring of another feature is begun. Should control alone be lacking, form lines (see below) should be lightly sketched in and advantage

thus taken of a favorable viewpoint, effort being made subsequently to cut in the lacking control. By treating each mass as a separate unit, each can be best delineated with its own characteristic shape.

*Form lines.*—Form lines are short detached sections of contour lines that are based on little or no control and on approximate contour intervals only. Form lines serve as a temporary expedient in expressing the relief of a small area until the necessary control can be obtained; they can then be readily converted into contour lines. Advantage is thus taken of a favorable point of view, and another visit to the same station is often avoided. In regions of moderate relief, where each feature takes but a few contours or where the mapping is done at short range, provisional sketching by form lines is not needed, but in many regions of intricately sculptured mountains it is a necessity.

*Distances from which contouring can be done.*—Where the topographic method used is that of mapping the country from a distance, as in station work by plane-table methods alone, the distance will vary according to the proposed mapping scale and contour interval. In general, the smaller the map scale the more distance should the country be from the stations in order that it may be properly seen, and the larger the map scale the nearer should the stations be to the detail that can be properly mapped only at short range. Where small-scale mapping is confined to country that is near the station, less area will be covered and more detail will inadvertently be attempted than is needed for the scale, with the result that only a small paper area will be mapped in a given time; where the large-scale mapping of a too distant country is attempted the needed detail is not well seen and inferior work will result. On the selection of the best distance for work and on the choice of stations depends much of the success of the topographer.

Effective working distances in the mountains may be as great as 5 to 10 miles with a 100 or 200 foot contour interval on a scale of 1:192,000, as great as 2 to 5 miles with a 100-foot interval on a scale of 1:96,000, and may range from a quarter of a mile to 1 mile with a 20-foot interval on a scale of 1:48,000. The cultural features of a country of bold relief should in general be separately traversed, and where they dominate the country the plane-table station method may become secondary.

#### DRAFTING OF CONTOURS

*Penciling.*—Contour lines should be drawn with the hardest pencil that can be used under field conditions, and this in general will be a 9H pencil in dry weather and a 7H pencil in damp weather or in a wet climate. The pencil lines should be drawn fine, sharp, and of even strength and should give as uniform an appearance as possible,

but under no circumstances should the lines dent the paper or leave grooves in its surface. Erasures should be made gently and only when the paper is perfectly dry, lest the surface be broken. As the same sheet will later be inked in the office, it should at all times be kept covered save where the day's work is being done, for which a small hole can be cut in the cover paper.

*Emphasized contours.*—Inasmuch as every fifth or fourth contour, according to the contour interval, will be later emphasized by inking it in a heavy line (see "Strength of contour lines," p. 294), the penciled contours that are to be made heavy in the inking should be indicated clearly, by adding contour figures at short intervals and by placing little penciled crosses on them rather than using dashed or dotted lines or heavy penciled lines. For steep slopes whose relief is expressed in emphasized contours alone no mark of identification is needed other than the drawing in here and there of a band of intermediate contours.

*Contour numbers.*—Contour numbers should be added to contours that are to be emphasized wherever such numbers may be helpful to the inker and should be placed here and there on the intermediate contours wherever they may be essential or helpful in the interpretation of the copy.

*Uniform steep slopes.*—Where the slope is both steep and uniform only the contours to be accented should be penciled, for the reason that the inker can interpolate the intermediate lines as readily as the topographer can pencil them in on the field sheet and for the additional reason that the inker's copy is the clearer for their omission. (See "Uniform steep slopes," p. 295.)

*Steep slopes that are not uniform.*—Where the slope is steep but not uniform a sufficient number of intermediate contours should be added to define clearly the positions of the changes in slope. If this is not done an unnatural "banded" expression will be given to the map in those places where the inker inadvertently uses an even spacing of intermediate contours between the unevenly spaced heavy contours.

*Drainage and ridge slopes.*—Along lateral stream channels and ridges that have been contoured in heavy contours alone the intermediate contours should be penciled in wherever a uniform interpolation can not be made; otherwise an erroneous interpolation may be made in the office with resulting improbable slopes, illegible copy, or both.

#### SPECIAL FEATURES

*Railroad grades.*—As railroads are constructed on known and definite grades they should be so represented in contours. The distances given in the following table apply to standard service roads and should be regarded as approximate only. Few main lines use grades in excess of 1 or 2 per cent, and few branch lines in excess of 3 or 4 per cent. For grades of 5 and 6 per cent unusual precautions are necessary, such



as heavy motive power and short trains; grades of 7 per cent or more require safety switchbacks.

*Distances, in feet, between contour crossings on railroads for different contour intervals and different railroad grades*

Railroad grade (percent)	Distance between crossings for contour interval of—				
	5 feet	10 feet	20 feet	50 feet	100 feet
1	500	1,000	2,000	5,000	10,000
2	250	500	1,000	2,500	5,000
3	167	333	667	1,667	3,333
4	125	250	500	1,250	2,500
5	100	200	400	1,000	2,000
6	83	167	333	833	1,667
7	71	143	286	714	1,429

*Cuts and fills.*—Cuts and fills that have straight and smooth slopes should be ruled in rather than drafted free hand. Cuts and fills paralleling cultural features should be drawn rigidly parallel to those features. Where the lines of a fill, plotted to scale, are so close together that the separate lines can not be shown by ordinary drafting, the contours should be slightly separated, provided that there is room on the map and no undesirable crowding of other map features is introduced thereby.

*Depressions.*—Natural depressions or sinks, such as occur in limestone regions, and artificial depressions, such as are inclosed by embankments, should be indicated on the field sheets by the addition of hachures on the downhill side of the contours inclosing them. Large depressions can be adequately shown without the hachures by placing rows of contour figures on the inclosing contours. In areas of intricate topography or in deep depressions bottom figures of elevation should be added wherever the contouring can not be legibly drafted. Hachures should be freely used on the field sheets, and the question of inking or of engraving them left for office decision. (See "Depression contours," p. 296.)

*Ditches, arroyos, etc.*—Where ditch contouring is congested and would be illegible to another person the expedients described below will aid the office inker in reading the copy. Where contour crossings can not be readily identified, each crossing should be designated at the end of a right line drawn to an open place within the map. Where the ditch is narrow and the side contour lines, when plotted to scale, touch the drainage line representing the ditch, the contours may be slightly separated, but this exaggeration is not warranted unless it can be accomplished without encroaching upon other essential map features.

*Cliffs.*—In the representation of cliffs a number of contours may be merged to form a wide line or band. Within such a band of



contours an emphasized contour would obviously lose its identity, and in such cases enough contours, both heavy and light, should be numbered in the vicinity of the cliff to insure a correct reading of the contours for office inking. (See "Cliffs," p. 295.)

*Use of hachures.*—The use of hachures should be confined to the representation of depressions, mine dumps (see p. 234), and levees and such other banks as can not be shown by the regular contour interval and yet constitute important topographic features, to be determined for each map.

#### TOPOGRAPHIC EXPRESSION

*Uses of the term.*—The term "topographic expression," in general, refers to the appearance of the contouring that denotes at a glance the character or type of the country that has been mapped—for example, as flat, mountainous, rolling, or strikingly eroded. The term as used by the Geological Survey, however, denotes the faithfulness with which a given scale, contour interval, or individual may represent the character of the country as shown on the map by means of the contouring. As between different scales, contour intervals, and individuals, on the one hand, and the numberless types and varieties of topography that are to be found in the country, on the other hand, the subject of topographic expression presents many phases.

The relation between the topographic character of a country and its adequate representation on a map is so close that experienced map readers and physiographers may be able to recognize from the map's characteristic expression in what part or parts of the country the map was made or may have been made.

*Topographic expression by different persons.*—Although the field drafting of contour lines is controlled by the location of certain salient points, contour construction, sometimes called contour sketching, is an art that is developed only through training and experience; and the contouring of two engineers working alongside each other in country of the same type will differ, not so much in the position of the contour lines on the map, for that is an engineering problem, but in the topographic expression. The less control that is available the larger will be the purely sketching functions of the topographer and the larger will be the differences that may be expected between the contouring of different engineers; and the larger the scale of the field work the smaller will be the differences that may be expected between the contouring of two or more persons using identical control.

Party chiefs should watch closely the contour expression of different persons working in the same or adjoining quadrangles and should take such steps as may be necessary to reconcile the differences in style that are found; and topographers working alongside each other should compare maps for the same purpose.

*Examples of differences.*—Differences in topographic expression may consist in the mapping of an excess of unessential detail or in the omission of essential detail that is within the scale of the mapping; in the exaggeration of small features that because of their striking character may appear larger than they really are; in the use of sharp or curved stream reentrants where the opposite should be used; in the sketching of conventional curves rather than the diversified curves that are normally found in nature; in the sketching of rounded forms, where in general the type calls for forms of more angular appearance, or the reverse; and in other minor mannerisms that occasionally appear, such as the inadvertent use by the engineer of certain typical shapes recently used by him elsewhere and not to be found in the new area under survey.

*Topographic license.*—In order to put all possible expressiveness into each contour line and in order to bring out prominent and characteristic relief that otherwise might not be shown, the topographer is occasionally justified in slightly disregarding an elevation determined for no purpose other than contour control. To force a contour into rigid conformity with an instrumental elevation and location where other contours are only sketched may result in a stilted form of detail adjacent to a control point and an appearance of relative absence of detail at a distance from the control point. Where elevations at sharp summits or on broad flats are just under a certain contour elevation, it is permissible license to add or move a contour and thereby bring out a conspicuous form. The need for such license is greatest where the sketching is being done with a large contour interval combined with a small scale, and in such places elevations may be disregarded for as much as 10, 20, or even 30 per cent of the contour interval, the amount depending upon the prominence of the topographic feature and the scale. Where the elevation of such a feature is important map information, figures of elevation should be added and the slight inconsistency between contour and elevation disregarded. As the scale of the map increases and as the contour interval becomes smaller, the need for such topographic license decreases, for then the contouring approaches an engineering accuracy and the individual contour lines approach true contours.

*Alinement of contours.*—The turning points of reentrant contours that define steep drainage channels should, in general, be in alinement with one another, and the closer the spacing of the contours the more exact should be the alinement. To insure accurate alinement the penciling of all drainage lines is essential. (See "Drainage lines as contour control," p. 244.) The penciled alinement of contours up reentrants, on ridges, and on side slopes should be so carefully and clearly drawn that the office inker will not be forced

to correct obvious errors that appear to be due to hasty or careless penciling.

*Physiography an aid.*—Contour lines, unlike most other map features, are largely sketched rather than completely surveyed, and thus contour sketching is an art as well as an engineering problem. The art of contour sketching consists of a free-hand delineation on paper, to the scale of the map, of the surface relief as seen in perspective view, but controlled by locations on the paper corresponding to salient points on the ground. However numerous may be the locations controlling a given contour line, it is always possible, so long as the locations are at an appreciable distance from one another on the paper, to give the line different significant shades of meaning, each equally justified by the control. That contour line therefore is likely to be nearest to the truth that is drawn with the fullest comprehension of the character of the feature expressed. The most accurate geometric representation of a land form may appear "wooden" or lifeless on a map unless it is also given its true characteristic expression. It is therefore desirable that the topographer have a sufficient working knowledge of some of the physiographic processes that sculpture, the earth's surface, in order that he may understand the type of land form with which he is dealing and realize wherein its peculiar character resides. Not only will the expressiveness of the contouring be enhanced by physiographic knowledge, but the early recognition of the prevalent topographic type forms will enable the engineer to place his control to the best possible advantage and in general will enable him to complete the contouring with less control. The smaller the scale of the map the more helpful will such physiographic knowledge be. Large-scale maps, on the other hand, are less of a problem, as all features that are not insignificant in size can be adequately shown on them.

Topographic engineers are encouraged to study topographic forms and to acquire an understanding of the elements of geology as a necessary foundation for the study of so much of physiography as may help them in their contour construction. The following references are suggested: "Interpretation of topographic and geologic maps," by C. L. Dake and J. S. Brown; "Physiography," by R. D. Salisbury; "Physical geography," by W. M. Davis; "Topographic surveying," by H. M. Wilson, Chapter VI, "Topographic forms"; and special texts on the back of several topographic maps.

#### MAPPING ON AERIAL PHOTOGRAPHIC BASE

If suitable aerial photographs and initial horizontal ground control are available the culture, drainage, and woodland outlines can, in large part, be delineated and the resulting base map used as a field plane-table sheet upon which the details of culture, drainage, and



woodland outlines can be completed and the contours constructed. The method of preparing the aerial photographic base is described in part F, "Map compilation from aerial photographs." The base thus prepared is reduced by photolithography to the scale of field work and printed in light blue on double-mounted drawing paper. Such a culture and drainage base is then used in connection with the usual initial vertical control, and the topographic map is completed, the further necessary field work being executed in conformity with the instructions for topographic mapping.

Each map feature shown in light blue, such as a road, house, or stream, should be penciled in as soon as identified and found to be correctly plotted, in order that the copy may clearly indicate to the office inker the distinction between these features that are to be inked and those, such as fence lines plotted for control use only, that are not to be inked. Faint blue lines that remain on the base field sheet and represent features that are not to be inked should therefore be erased or crossed out in pencil; otherwise they may be taken to represent cultural or drainage features and erroneously inked.

Inasmuch as aerial photographs of shore lines may be taken at any stage of water ranging from high to low, the shore line thus represented may accordingly differ from the shore line that should be mapped, which on tidal coasts is the margin of mean high water and on inland rivers is that of the normal stage of the water. (See pp. 242, 243.) The stage of water that is shown on the aerial photographic base should therefore be ascertained by observation on the ground supplemented by local inquiry. If coastal photographs have been taken at any stage below mean high tide or if inland photographs have been taken during a period of high or low water the photographed shore line should be corrected by instrumental observations and based upon local information so far as practicable. A photographed shore line can represent the desired shore line at all stages of the water only where steep banks or the scale of the mapping renders the differences inappreciable.

#### **SAND**

Sand above the level represented by the plotted shore lines, where devoid of vegetation, should be represented by the sand symbol, with the limits of the sand area indicated in pencil.

#### **MAPPING OF WOODLAND OUTLINES**

The outlines of woodland areas as defined below should be mapped. The accuracy in the location of woodland outlines for maps to be published on a scale of 1:62,500 will be based upon the location of the principal salient features only, the intermediate details between located points being sketched. In general, the location of the four



corners of a small quadrilateral tract and additional locations of the principal bends in the outline of a large tract will be sufficient.

*Definition of woodland.*—Woodland to be mapped includes all timber, woods, or brush, whether alone or mixed, of sufficient stand and height to impede ordinary travel or afford cover for small detachments of troops. Logged over or burned areas, if covered by second growth or brush, should be shown as woodland.

*Woodland sheet.*—Although woodland outlines must not be inked on the final drawings of topographic maps the penciled woodland outlines may be added to the field sheet if this is found more convenient than laying a tracing over the field sheet each time woodland outlines are plotted. In either event a woodland tracing should be made and kept current. This tracing should be complete as to the woodland outlines before leaving the field. It can be most conveniently made in two halves for a standard quadrangle. Where two or more engineers are engaged in mapping a given half of a quadrangle at the same time, each man should make his own tracing, but their common edges should be compared before field work is completed, and, if practicable, a combined woodland tracing should be made for the entire half quadrangle.

*Woodland data from aerial photographs.*—If woodland outlines are shown on the aerial photographic base they should be checked in the field as the topographic mapping progresses, and a woodland sheet should be prepared by adding a green shading to the checked or corrected woodland areas as printed on an extra copy of the aerial base provided for the purpose.

## ROAD CLASSIFICATION

### ROADS SHOWN IN BLACK

The first classification of roads determines those roads that are to be indicated on the base by solid double parallel lines and those that are to be shown by broken double parallel lines; and these classification symbols should be penciled on the original field sheets and will be later inked and engraved in black. (See "Roads," pp. 229–230, 284.)

### ROADS SHOWN IN RED

A further classification of roads will be indicated by means of a red overprint on all new standard topographic maps, and the topographer should make the necessary observations or local inquiries to obtain field data for this classification, which should be submitted on a tracing or other separate sheet (not combined with other information), marked at the top "Road classification."

The distinction between through and secondary routes shown by means of a red overprint on many published topographic maps for

which the surveys were made from 1920 to 1926, inclusive, will be discontinued in all new surveys, and the road classification described below will become effective. The following instructions are based upon an agreement between the War Department and the Department of the Interior, approved September 8, 1926, and upon a report on road classification approved by the Board of Surveys and Maps December 14, 1926:

*Full red lines.*—Full red lines should be used to indicate "hard, imperviously surfaced roads." A hard, impervious surface is defined as a road surface of the dustless order and includes such artificial surfaces as concrete, brick, and all bitumastic mixtures or insoluble surface treatments. A hard, impervious surface excludes such surfaces as water-bound macadam, gravel, top soil, sand, clay, and all graded or ungraded earth roads. Detached stretches of hard-surfaced road should be shown as detached, but a hard-surfaced road that is only temporarily in poor condition should in general be shown by a full red line.

*Broken red lines.*—Broken red lines should be used to indicate "other main traveled roads," defined as those roads that are most traveled whether for purely local use or for through travel. The selection of these roads has no reference to character or condition of road surface. In sparsely settled regions a road may be difficult to travel, but if it is the only practicable route through a country of few roads it should be shown in broken red lines. In regions where poor roads abound the best among them usually carries certain local or through travel, and such roads should be similarly shown.

In regions of prevalent hard-surfaced roads the full red lines may cover so many of the main traveled roads that little if any representation by broken red lines will be needed. Where ambiguity might arise in the indication of short detached stretches of hard, impervious surface and of other main traveled roads, the hard-surfaced stretches should be marked "hard" on the tracing.

*Objectives and distances.*—On the margin of each quadrangle map should be indicated the names of the next main objective and the next immediate objective of each road shown in red, with the distances thereto in miles.

*Date.*—On the lower margin of the road-classification tracing should be shown the month and the year of the road information.

#### ROAD AND HIGHWAY NAMES

Well-established names for roads and highways, including route numbers or other recognized designations, should be indicated on the name sheets and will be published so far as Geological Survey policy provides; but such data will not be overprinted in red and should be omitted from road-classification tracings.

**MAPPING OF LAND-CLASSIFICATION DATA****GENERAL REQUIREMENTS**

Each topographer engaged in mapping areas in the States of Minnesota, Nebraska, Kansas, Oklahoma, New Mexico, or States west of them or areas containing public lands, national forests, or national parks in the States east of them must make the field observations and local inquiries necessary to enable him to submit to the conservation branch a land-classification tracing and written report containing such data as will indicate the possible uses of the lands which he maps.

Such reports will be based only upon facts personally observed by topographic engineers or their assistants or obtained by them through inquiry from known and reliable sources.

The general character of the information desired by the conservation branch will appear from the following list of subjects on which it is required to report to the Director for his submission to the Secretary of the Interior:

(a) Designations of (1) areas which are not susceptible of successful irrigation at a reasonable cost from any known source of water supply and which can therefore be entered under the general provisions of the enlarged-homestead act (as suitable for dry farming); (2) lands in certain arid States which do not have an available supply of water (either surface or ground) for domestic purposes such as to make continuous residence on the land possible.

(b) Recommendations as to withdrawals of lands for water power, reservoirs, and public watering places.

(c) Recommendations for the protection of mineral resources and for other public uses.

(d) Reports on the valuable power-site and reservoir possibilities involved in (1) applications for rights of way for railroads or for canals, ditches, reservoirs, etc., included in power and irrigation projects; (2) proposals for alienation of tracts of land in Indian reservations and in the public domain under any of the laws providing for such alienation; (3) designations by Congress for special alienation or use of whole Indian reservations and other areas.

The conservation branch should be notified of the presence of any deposits of coal, oil, gas, or phosphate, the topographer bearing in mind that it is much better to report facts that may be already possessed by the Geological Survey than to fail to report facts that are not on file. The land-classification material thus submitted will be filed with the other records for the area covered and with them will become the basis for recommendations to the Secretary.

For the purposes of the conservation branch it is essential that enough land corners be identified on the ground and located on the

map to enable the best possible adjustment of the land-line net to be made. The land should finally be classified by the smallest legal subdivisions, and the immediate availability of the classification data reported depends on its definite application in terms of the land-office surveys to the land described.

#### LAND-CLASSIFICATION SHEET

A sheet must be prepared that will show the classification of the land in accordance with the general outline and symbols described below. The base for this sheet will be the topographic map of the area covered, but the classification should be inked on tracing cloth, on which all projection lines should be fully shown and numbered. When transmitted to the conservation branch it should be attached to a photolithograph or photograph of the topographic map on the same scale.

An accompanying written description should explain and amplify, where necessary, the information given on the classification sheet and should include all facts which can not be clearly shown graphically, including the character of each examination. The description should, so far as practicable, be arranged in the order followed in the list of symbols given below and should be arranged in paragraphs, with headings corresponding to those there given, including the index letters. This description should include a discussion of the usual money value of the different classes of land in the locality, so far as known. The description should be appropriately headed, and each page should be so designated that if separated from the others it could be quickly restored to place.

The outline and sets of symbols shown in Figures 9, 10, and 11 and described below should be used in preparing agricultural data for submission to the conservation branch. The system permits the overlapping of different classes of lands to be shown. For example, land bearing merchantable timber may be good summer grazing land, and these facts may be indicated by vertical lining and the letters "F t" in green and by vertical lining and the letters "G s" in yellow.

The boundaries between the four principal divisions as listed below should be inked in black. The boundaries between the subdivisions of a principal division should be inked in the color of that division.

1. Forest land (fig. 9; green ruling):

F t Merchantable timber.

F s Small or stunted timber which may be used for posts, firewood, etc.

F b Burnt areas.

The kind of timber should always be described in the accompanying text, and where possible its kind should be indicated on the classification sheet.



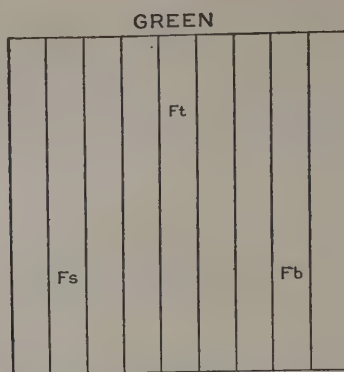


FIGURE 9.—Pattern and symbols for designation of forest land

2. Arable land (fig. 10; red ruling):

C Cultivated land:

C i With irrigation.

C d Without irrigation.

I Lands not cultivated but which may be irrigated:

I s Irrigable directly from streams or springs. State unappropriated water rights if known; if unknown, so state.

I r Irrigable from possible storage reservoirs.

I w Irrigable from wells. Give geologic source if known.

p Irrigable only by pumping from any of the preceding three (add "p" to other letters; as, I s p).

D Lands that may be cultivated without irrigation (dry farming).

S Swamps:

S e Easily or readily drainable.

S d Drainable with difficulty.

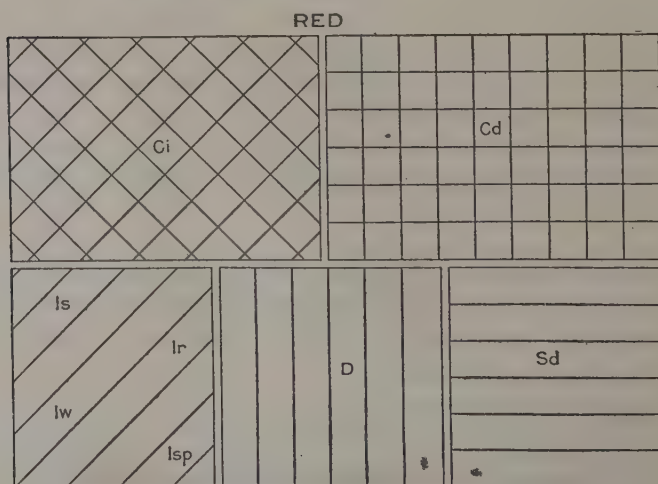


FIGURE 10.—Patterns and symbols for designation of arable land

## 3. Grazing and natural hay land (fig. 11; yellow ruling):

H Lands with sufficient natural grass to cut for hay.

G Grazing lands not included under "H." Indicate on classification sheet where practicable the character of the vegetation and the duration of the range:

G y Year long.

G s Summer.

G w Winter.

## 4. Barren or waste land (no pattern):

B a Alkali flats.

B r Rock wastes, escarpments.

B s Sand wastes.

B x Other barrens.

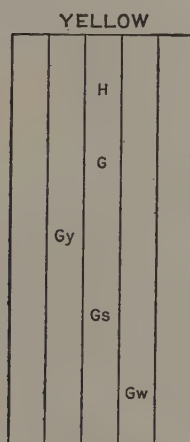


FIGURE 11.—Pattern and symbols for designation of grazing land

## AGRICULTURAL WATER SUPPLY

## Wells:

## Character:

⊕ Flowing.

○ Nonflowing.

## Description:

Dug or drilled.

Diameter and depth, indicated thus: 3'×168'.

Yield, where well is pumped or where well flows.

## Quality of water:

m Mineralized.

du Suitable for domestic use.

st Stock use.

rr Railroad use.

## Ownership.

## Springs and watering places:

Location.

Description.

Quality of water (as for wells).

Uses (domestic, stock, etc.).

Ownership, public or private. If private, name of owner or occupant.

Area of range controlled.

## REVISION OF TOPOGRAPHIC MAPS

## REVISION DEFINED

The topographic surveys of the Geological Survey are classified as new surveys, resurveys, or revision. Resurveys are made under the same specifications used for new surveys on the same scale. By revision is meant an examination of all or a certain part of a map, as its cultural features, in order to bring it up to date. A cultural revision will involve only so much new survey as may be needed in order to add new cultural features to the map and tie them in to the cultural features that are unchanged, and it will involve only so much change in the drainage and relief features as may be needed to fit them properly to the new or changed cultural features. Where the cultural revision is extensive, owing to a rapid growth or to a long interval of time since the original survey, correspondingly extensive changes in the drainage and relief features may be needed. In proportion as the revision of the culture, drainage, and relief of a quadrangle becomes more and more extensive, however, the revision partakes more and more of the nature of a resurvey. A revision is therefore seldom more extensive than a so-called "cultural revision." The choice between a cultural revision and a resurvey can be made only after a knowledge of local conditions has been obtained and combined with an appraisal of the character of the original survey.

## CULTURAL REVISION SURVEY

*Personnel and instrumental outfit.*—A revision party need seldom consist of more than one topographer in charge, assisted by one rodman. The instrumental outfit will be similar to that used by a topographic party of the same size. The methods employed should largely conform to those in current use for new surveys in similar country mapped on the same scale.

*Use of control data.*—The control data that were used in the original survey are shown on the published map, with the exception of a few intermediate points that were determined for control but not for publication. Horizontal positions that have been determined since the time of the original survey should be plotted on the revision field sheets, and where the plotted positions disagree with the published adjustment of the adjacent topography a readjustment of the topography should be made if the discrepancy is but local, but if the disagreement covers a considerable area the matter should be at once reported to the division chief.

If leveling has been done in the quadrangle since it was originally mapped, the newly determined elevations should be compared with the contouring, and such differences as are found should be noted for a field examination and the correction of the contours.

*Control stations to be published.*—All transit-traverse stations and level bench marks falling along or near the line of cultural revision should be systematically looked for, and where they have been destroyed or moved the symbols should be crossed out on the field sheet and the change should be reported to the Washington office for the correction of office records; where they are found intact they should be indicated in pencil on the field sheet as clear copy for office inking and subsequent publication. All newly established transit-traverse stations and level bench marks should likewise be shown in their correct relation with the topography. Newly established triangulation stations should also be shown, provided the adjacent topography can be properly tied in to them.

*Scope of cultural revision.*—The features to be included in a cultural revision are those listed under "Mapping of cultural features" (pp. 229–242).

*Examination of cultural features.*—The field work should consist in traveling over each road or other route of travel within the quadrangle and comparing each cultural feature with its corresponding representation on the map. Where new or changed features are found they should be surveyed and tied into the features that are not changed or to the horizontal control or some form of expansion from the control. It is imperative that the topographer know his true position in the quadrangle at all times, and for this purpose plane-table set-ups, traverses, or plane-table stations must be made wherever they may be needed.

The comparison between ground features and the corresponding map features must be thorough and complete and should include an examination of the direction, length, and angle of bend of each stretch of road, trail, railroad, or other line feature; a check of each house or other building; and a lookout for all other cultural features. A definite plan should be adopted in order that no part of the culture shall be overlooked in the examination. All existing houses and other small cultural features, including control stations and bench marks, should be clearly indicated by firm penciling over the faint color representation of the features or shown in their plotted positions where they are new features. Features that have been destroyed or abandoned should be so indicated on the "take out" sheet (see below) and the symbols also crossed out on the field sheet.

*Boundary lines.*—Each boundary shown on the map should be verified, and an inquiry should be made for new or changed boundaries and for the names of the subdivisions affected. The boundaries of cities or other places that have been incorporated since the first survey should be added.

*Names.*—Each name on the map should be as thoroughly verified as the names for a new survey; names of new places and features



should be added; names that have fallen into disuse should be dropped but replaced if other names are found in current use. Where a post office has been discontinued owing to the introduction of rural free delivery, the name of the former post office should be retained if it represents a well-established locality. In short, every effort should be made to bring all names up to date. Each name should be recorded as soon as obtained, and this record may be made on the revision sheet, on a tracing, or on a copy of the published map.

*"Take out" copy.*—Where a map feature has been abandoned or destroyed, as a road or a house, the corresponding copy on the copper plates must be smoothed out and "tapped up" to a flat surface. Engraver's copy for such "take outs" should be recorded as the revision field work progresses and may be conveniently indicated on the field sheets by penciled crosses or by wavy penciled lines placed on the features that are to be removed from the plates; but lest there be confusion in the final copy such "take outs" must be transferred to a clean published print of the map and later inked. The sheet so used should be marked at the top "Take out sheet."

*Woodland.*—No revision of woodland outlines will be made unless instructions are issued authorizing such work. Inasmuch as a cultural revision is confined largely to rapid travel over routes of communication, such as roads, and inasmuch as woodland representation can not be revised but must be remapped, a resurvey of the woodland areas is seldom attempted during a revision of culture, for the reason that it requires much more traverse and map work than for revision of the culture alone.

*Road classification.*—The roads should be first classified according to the instructions given under "Roads" (p. 229). Where it is found necessary to change from a full to a broken line or the reverse, such changes should be indicated on the "take out" sheet by inking the road in full or broken lines where such changes are needed.

The roads should be further classified as defined under "Road classification" (p. 256), and this classification should be placed upon a separate engraved copy of the map and not combined with any other data and should be marked "Road classification."

#### CULTURAL REVISION BY AERIAL PHOTOGRAPHY

*Scope of revision.*—The cultural features of a topographic map may be revised by the use of aerial photographs, a procedure that promises increasing usefulness as the photographs and the methods of using them are further improved. The drainage features of the map may also be thus revised where revision is found to be necessary or desirable. A field examination may or may not be needed, as explained below.

*Good base necessary.*—The use of aerial photographs in topographic map revision should be confined to maps for which the original surveys were well controlled and the topographic details properly adjusted. If the map that needs to be revised has been insufficiently controlled or incorrectly adjusted the data that are obtained by aerial photographs can not be successfully used until the base map has been readjusted, and such a readjustment can not be made until further control has been supplied, involving field work. Inasmuch as such a procedure is not generally warranted, the revision of such a map can best be effected by means of a complete resurvey.

*Type of photographs.*—Maps of cities and towns and of other areas that are closely built should be revised through the use of photographs taken with single-lens rather than multiple-lens cameras, because the single-lens vertical photographs show clearly the width of streets and the plan of buildings on each side of them, whereas the wing-print parts of the multiple-lens photographs represent exposures taken at an angle and show objects in such increased perspective that high buildings and even ordinary dwellings obscure streets and render the ground plan of buildings indefinite. Multiple-lens photographs are suitable, however, for the revision of maps of sparsely settled areas.

*Office use of photographs.*—The revision corrections that are obtained by an office compilation of the data found on aerial photographs should be drafted on an enlarged (field scale) photolithograph of the map printed in light blue on drawing paper. It may be advisable to use transfers from the engraved plates (on the same scale or enlarged) and print from stone in three distinctive and weakly photographic colors. The additions and corrections to the map can then be inked in the standard strong colors, such as will yield photographs showing only the revised data.

In the process of compilation each aerial photograph is used as a separate source of data, either by photographing the aerial print to the scale of the map and tracing the map features desired, or by using the original aerial photograph directly and taking off the features desired by means of proportional dividers. If the map that is to be revised is well controlled and adjusted, a careful comparison of the aerial photographs and map will determine the existence of new features and the need for possible correction of the old.

*Field examination.*—When the office revision of the culture and drainage has been completed there may be need for a field examination in order to revise the contouring slightly to fit the new culture or drainage. The need for a field examination will depend upon the accuracy of the base, the nature of the topography revised, and the extent of the revision. Features obscured in the photographs by heavy timber may also need a field examination.

The better the control and adjustment on which the map was based the less will be the need for a field examination. If a cultural feature is added to the map on or near a line of previous control the necessary changes in the contouring will be small and may generally be made from a close examination of the photograph, but if a cultural feature is added to the map in a place that falls between control lines that were not near together the need for a field examination will be increased.

A careful comparison of the photographs with the contouring adjacent to the revision copy will show that in certain types of country the necessary changes in the contours can be made from the photographs alone, but where there are numerous and rapidly changing land forms the need for a readjustment of the contours will be greatest, and in general a field examination is more likely to be necessary. In country of certain types the relief expression would be but little changed, if at all, by a field examination, and here the chief advantage gained would be in the determination of the actual elevations along the newly added features, a determination that has not yet been attempted by the Geological Survey from aerial photographs alone.

If the revision results in extensive corrections throughout the quadrangle or in complete changes within smaller areas the need for a field examination will be increased. Inasmuch as a large part of the expense of a field examination may be incurred in connection with preparation and in travel to and from the field, it is obvious that where it is found necessary to make a field examination the fullest advantage should be taken of the opportunity to visit all localities where contour changes may be needed. Such a field visit would also permit the examination at the locality of any doubtful adjustment or place where the interpretation of the aerial photographs was uncertain.

## RIVER SURVEYS

### SPECIAL RIVER SURVEYS

Special river surveys involving the delineation of alinement, water-surface contours, and adjacent topography and the construction of a corresponding profile are executed for all important streams that may be designated by the conservation branch of the Geological Survey.

Special supplemental instructions are prepared by the conservation branch for each locality of special river survey. If a representative of that branch accompanies the topographic field party, the topographic engineer will be relieved from the necessity of collecting the information outlined on pages 270-271 under "Written reports."



Special river surveys should be executed on the scale of 1:31,680 (2 inches to 1 mile), except as provided for in connection with regular topographic mapping.

#### RIVER SURVEYS IN REGULAR TOPOGRAPHIC MAPPING

In connection with or as a part of all regular topographic mapping on field scales of 1:96,000 or 1:48,000, river surveys of all important streams should be made on a uniform field and office scale of 1:48,000. For this purpose important streams may, in general, be defined as those that have a low-water flow of at least 10 cubic feet per second and also a product of at least 2,500 for fall in feet per mile multiplied by the low-water flow in cubic feet per second. On a scale of 1:48,000 the requirements as to detail that it is possible or desirable to show are considerably less than on larger scales.

Where regular field work is executed on a scale of 1:31,680 or 1:24,000 the river surveys and profiles should be made on the same scale.

Where the regular field work is on a scale of 1:48,000 the principal additional work involved in making river surveys will be the location of 5-foot water-surface contour crossings and the determination of the elevation of the head and foot of falls, dams, and rapids and the elevation of the junction with tributary streams. Where the regular field work is on a scale of 1:31,680 or 1:24,000, no additional contouring will be necessary if the contour interval for the quadrangle is 5 feet.

In connection with field work executed on the 1:192,000 scale, only written reports as to important streams will be required. Reports should be based on such general observations and local inquiries as can be made without materially delaying the regular field work.

#### TOPOGRAPHY

The following instructions apply to both special river surveys and to river surveys made in connection with regular topographic mapping.

The field traverse sheets when carefully inked should serve as final copy for assembly on the plan sheets and for data from which corresponding profiles may be made on separate sheets.

*Contour intervals on water surface.*—The contour interval on water surfaces should be 5 feet, and care must be taken to furnish clear penciled copy for office inking. In addition, the elevations at the head and foot of all falls, rapids, and dams and at the mouths of principal tributaries must be determined. Where the stream slope is so steep that a 5-foot water-surface contour interval can not be readily shown, the interval should be increased to 20 feet; beyond



this the interval may be increased to 100 feet, but only where demanded by legibility.

*Contour interval on land.*—The contour interval on land along river stretches should be 20 feet, but wherever a 20-foot office interpolation can be accurately made between the 100-foot contours the 20-foot contours should be omitted and only 100-foot (heavy) contours drawn.

*Tributaries.*—The topography of each tributary or side channel should be shown up to the limiting contour. In addition, the larger tributaries should be shown with topography for about a quarter of a mile and then be sketched as far beyond as possible; for this purpose one or more additional set-ups may be taken if practicable.

*Topography to be shown.*—The land features, including all culture usually found along streams but excluding large valleys or cities, must be accurately and completely surveyed by additional set-ups, intersections, or side traverses. The work should be done in such a manner that the data can later be incorporated in topographic maps when such areas are regularly mapped.

In the absence of special definite instructions the topography as outlined above should be mapped to an elevation of 200 feet above the stream and may be sketched for another 100 feet or more if such higher sketching can be done without additional set-ups. Mapped topography should be indicated by full lines, but where uncontrolled topography is sketched it should be drawn in dashed lines, to be clearly distinguishable.

To facilitate use of the field sheets by office engineers penciled figures of elevation must be placed wherever they will be legible, and numerous penciled contour numbers should be placed on intermediate as well as on emphasized contours.

*Gaging stations, dams, etc.*—All gaging stations must be located, and the elevation of the zero of the gage given. The ownership, whether United States Geological Survey, Weather Bureau, Army Engineers, or private, must be stated.

The location of all dams, power houses, canals, flumes, penstocks, and points of diversion should be shown, with elevations above and below all dams and power houses.

Rapids should be indicated by means of the conventional sign, which, however, should not obscure contour crossings or other important data.

Long azimuth lines should be drawn on each separate traverse sheet.

*Land lines.*—In sectionized country it is important that the land net be placed upon the sheets with an accuracy suitable for 40-acre references. Inasmuch as the width of a river survey is narrow at best, the search for all existing corners that may be found within the

belt of the survey should be systematic and diligent. (See field instructions, p. 239.)

Party chiefs must procure reproductions of Land Office plats, which preferably should be photographs furnished on office requisition. They should also ascertain if any such plats are under suspension by the General Land Office and procure copies of the notes of all such retracements or exterior notes of townships not sectionized as fall within the limits of the river survey. General inquiry should also be made whenever practicable at the local United States land offices. Existing maps or plats showing corners previously found, such as those issued by the Forest Service or by railroad, power, irrigation, and other companies, should be systematically looked for and procured whenever possible. Inquiry should be made through deputy mineral surveyors, county surveyors, and local engineers as to the existence and location of known corners or ties.

*Vertical control.*—In order that river surveys may be referred to sea-level datum the starting point of the line should wherever possible be tied to the nearest Geological Survey or other adjusted level bench mark before the survey begins; the elevations should also be tied to all other bench marks encountered in the course of the work. Owing to the difficulty of rerunning a line of river traverse extreme care should be taken both in the observations and in the notes, in order that errors in elevation may be avoided.

*Horizontal control.*—As river surveys are based upon a plane-table traverse line that is subject to no horizontal control, every effort should be made to reduce the errors of observation and plotting to a minimum, and to this end each stadia reading for distance should be twice read and each plotted distance checked.

#### RESERVOIR AND DAM SITES

The relations between possible reservoir sites and possible dam sites should be frequently observed as the work progresses in order that the survey of these two counterparts may illustrate to the fullest the natural storage possibilities. In considering the practicability of a reservoir site the character of the improvements and industries and the amount, kind, and distribution of the timber within the site should be noted and the value of the land to be submerged should be estimated.

The contours within reservoir sites should be accurately determined on a 20-foot interval up to the height of the possible dam. Ten-foot intermediate contours should be surveyed, drawn in close-dashed lines, and numbered wherever an office interpolation if erroneous would seriously affect an estimate of storage—that is, wherever an irregular spacing of 10-foot contours extends over a considerable area.

Special large-scale surveys should be made of dam sites favorably located in regard to reservoir sites whose existence has been previously ascertained by survey, with 5 or 10 foot contours up to the height of the practicable dam or storage. The scale for dam-site surveys will be indicated by the conservation branch but in general will be from 100 to 500 feet to 1 inch. The depth of water at the dam site and the character of bottom and abutments should be noted wherever possible. The elevation of the water surface should be shown for each dam-site survey.

#### WRITTEN REPORTS

Signed written reports on river surveys, accompanied by photographs when practicable, should be submitted in general conformity with the following instructions, except that map references should be made either to the plan sheets or to an advance sheet of the quadrangle map. Many desirable facts pertaining to small streams can receive all necessary attention in the written report.

*Stream flow.*—An approximate estimate of stream flow should be obtained a short distance below the mouth of each major tributary. The date of observation and the stage of the water should be noted. Measurements should be made, if possible, at a straight and uniform stretch of water about 200 feet long, free from rapids and cross currents. The velocity of the current in linear feet per second should be obtained by timing floats (chips) over a measured (stadia) course and using an average of two or more floatings made in or near mid-stream and nearer shore. The mean cross section in square feet may be assumed to be the mean of the cross sections at the two ends of the stretch. The individual cross sections are obtained separately by multiplying the local width (stadia or intersect) by the corresponding average estimated depth. The desired stream flow (discharge) in second-feet is obtained by multiplying the velocity in linear feet per second by the mean cross section. Example: Course 200 feet; floats average 100 seconds in transit; upper and lower cross sections are 300 and 400 square feet, respectively;  $2 \times 350 = 700$  second-feet of stream flow.

Estimated flow of all important tributaries should be obtained in the same manner.

As the minimum low-water flow denotes the maximum availability of the stream without recourse to storage, and as the high-water flow in large measure gives its availability for storage, all reliable information bearing on these points that it is practicable to obtain should be sought, and all information regarding the range of water stages, including data as to past floods or extreme low water, with dates, should be recorded.



*Water power.*—All dams or other existing natural sites for water-power development should be located and described. If any present development exists, the ownership, character, abutments, possibility of increasing height, and condition of stream bed should be recorded.

The plan and profile sheets of all dam and reservoir sites determined by the river survey should be supplemented by all obtainable pertinent facts. Any favorable stretches of stream that might be of value for developing power should be noted. The essentials are a diversion-dam site (intake), a site for a waterway alongside (canal or conduit), and a combined site for a relatively short pressure pipe line and for a power plant on the shore. Favorable sites for diversion of water for irrigation should be noted.

Information should be collected by observation and by local inquiry as to (1) power development, including location of existing or proposed power plants, points of diversion, location and capacity of conduit, amount of head available, location of power house, point of return of water to stream, installation and rating of turbines and generators, location, equipment, and ownership of power-transmission lines; (2) reservoirs, including location, height of dam, capacity, use, and ownership; (3) irrigation works, including canals and ditches, points of diversion, capacity, location, and ownership; (4) municipal water-supply systems, including location of pipes, source of water, etc.

*Character of adjacent land.*—The belt of topography mapped should be classified as to kind, amount, and distribution of timber; extent of cultivated areas; existence of grazing or natural hay lands and duration of range; and extent of barren or waste lands.

#### ENDING FIELD SEASON

*Work turned over to another.*—If unfinished field work is left for a successor to complete he should be provided with a list of the field sheets and other important field data that are turned over, also a memorandum of the condition in which the work is left, with copies of the original field instructions, including supplemental instructions that may have been issued. He should have a clear understanding as to where there may be need for additional inquiry regarding names or other data—for example, the status of power lines, road classification, and city boundaries.

*Completing field work.*—In order to insure against omission of field data the information sheet, name sheet, road-classification sheet, and woodland sheet should be checked over for completeness before making plans to leave the field. The plane-table sheets should be looked over for completeness and legibility.

*Shipment of map material.*—In general, all field sheets completed before the end of the field season should be shipped to the office



rather than retained in the field; tracings, however, should be made of map borders needed for further field joining. All map material should be shipped by express or registered mail to the chief topographic engineer at Washington or, if so instructed, to the division chief in charge of a field office. All original and duplicate record books such as level and bench-mark books should be forwarded by registered mail on different days. A letter of transmittal covering each shipment of instruments, maps, or records, and a list of all items should be sent under separate cover. If any maps or map material is carried to Washington in personal baggage, it should be delivered immediately on its arrival at the office to the section of inspection and editing for recording.

*Monthly field reports.*—See “Reports of field parties” (p. 19, part A). Reports should be complete so far as the data asked for are concerned or so far as they apply to the work in progress, and, in general, they should be confined to the data for which columns and spaces are provided. Promptness in the submission of reports is necessary because of the routine described under “Monthly office report routine” (p. 277).

## OFFICE WORK

### SCOPE OF OFFICE WORK ON TOPOGRAPHIC MAPS

The office work in connection with topographic mapping consists in preparing the field sheets as copy for reproduction and in the reproduction of the maps. The preparation of the copy and the proof reading of reproduction is done in the topographic branch, but the reproduction of the maps is done in the engraving division of the Geological Survey. The office work of triangulation, transit traverse, leveling, and map compilation from aerial photographs is described in parts B, C, D, and F of the “Topographic instructions.” In general, the sequence of the office work in topographic mapping is as outlined below.

*Assembly.*—The field sheets representing the completed topographic mapping should be assembled into as few final sheets as practicable, preferably into two half sheets representing the north and south halves of the quadrangle. The two half or other sheets should be cut at their common sheet borders and by transfer of topography where necessary made complete copy when fitted together. Where final topographic mapping has been done on separate field sheets other than on the principal north or south half sheets, such separate field sheets should be stripped and pasted in position on the principal half sheets on which they fall. (See “Transferring,” p. 282, and “Pasting,” p. 283.) The field sheets should be assembled and completed in pencil before the inking begins, if this is practicable,

inasmuch as the inking of the map can then go forward without the delays incident to joining the interior edges that may be on several separate field sheets.

*Adjustment.*—The results of separate traverse surveys that may not have been adjusted in the field should be completely adjusted into position on the final field sheets before these sheets are assembled or inked. (See "Adjustment of traverse lines," p. 212.)

*Inking.*—When the penciling and adjustment and preferably also the assembling of the final field sheets is complete they should be inked. (See "Inking of topographic field sheets," p. 277.)

*Lettering.*—When the inking of the map has been completed it should be lettered. (See "Lettering of topographic field sheets," p. 304.)

*Checking.*<sup>3</sup>—When the topographic map has been completely inked and lettered and before it is reproduced in any form the inking and lettering should be checked by someone other than the one or more engaged in the inking. (See "Checking of inked field sheets," p. 310.)

*Inspection.*—Prior to the submission of final map drawings for advance-sheet photolithography they should be passed upon by the section of inspection and editing to insure general conformity with standard practices. (See "Inspection of topographic maps," p. 313.)

*Advance sheets.*—Completed topographic map drawings are first reproduced by photolithography and issued as "advance sheets subject to correction." (See "Advance sheets," p. 317.) Advance sheets are intended to serve the immediate needs of engineers and others pending the publication of the engraved map, and they also serve as a basis for corrections, which are invited from any competent source.

*Control examination.*—Each topographic map should be examined in the section of inspection and editing for the correctness of its representation of the primary control features of the map. (See "Control examination," p. 319.) The control examination should be made before the map is edited for engraving or before it is photolithographed if the map is to be reproduced by photolithography alone. The control examination is usually made after the advance sheets have been issued but may be made before.

*Editing.*—Each topographic map that is to be regularly published by the Geological Survey, whether by engraving or by photolithography, must be edited prior to its submission for final reproduction. (See "Editing of topographic maps," p. 320.) The map editing consists in a critical review of the map for its general coordination and conformity with Geological Survey instructions and policies and in

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<sup>3</sup> The term "proof reading" has long been used in the topographic branch both in its ordinary sense, meaning the reading of proof, and in reference to the checking of manuscript maps preliminary to the inspection and advance-sheet photolithography by others than those who have done the work. For this special sense the term "checking" will be used hereafter.

the preparation of special instructions for its engraving or other reproduction.

*Engraving.*—Most topographic maps of the Geological Survey are reproduced by engraving on copper, from which transfers are made to the printing stone or metal. (See “Engraving of topographic maps,” p. 336.) The engraving is done in the engraving division of the Geological Survey.

*Proof reading of engraved maps.*—Proofs from the separate copper plates and combined stone proofs from the final printing plates for each topographic map that is reproduced by engraving are read by the section of inspection and editing.

*Reprints of topographic maps.*—When the map-room stocks of topographic maps become nearly exhausted reprints are requested by the division of distribution. The section of inspection and editing prepares the reprint copy. (See “Reprints of topographic maps,” p. 340.)

*Monthly office reports.*—See “Office reports” (p. 19, part A). Inking should be reported in terms of square miles inked and not in percentage of area. The column headed “Sq. mi. mapped” should agree with the total area reported as mapped. Inasmuch as a report on the number of square miles inked each month is intended to indicate approximate progress only, the figures need be given only to about the nearest 5 per cent, which for a 15' quadrangle would be to the nearest 10 square miles. As the inking approaches completion the accuracy of reporting should increase, and for this purpose the uninked area can be readily measured.

Where culture and drainage only have been inked such inking should be converted into an approximate equivalent expressed in square miles, in order that the inking report may give an index of progress. For example, if the total culture on the mapped area is roughly estimated to represent 30 per cent, the drainage 10 per cent, and the contours 60 per cent of the time needed to ink the sheet, and if half the culture has been inked but no drainage or contours, then one-half of 30 per cent, or 15 per cent, of the total area mapped should be reported as having been inked, and this for a quadrangle covering 240 square miles would represent an equivalent of 36 square miles inked, which may be reported in round numbers as 40 square miles. A statement showing total areas inked to date, listed by States, quadrangles, and months, may be obtained on request from the section of inspection and editing, where the data are filed in a book kept for the purpose.

#### MISCELLANEOUS OFFICE WORK

*Field sheets to section of inspection and editing.*—All field sheets and field map material reaching the office from the field must be at once delivered to the section of inspection and editing, where they will be



inventoried, filed under the name of the quadrangle or project, and made promptly available for issue for office work. Each separate original field sheet, traverse sheet, tracing, file of notes or plats, miscellaneous map, or other field map material will be listed in ink on the front cover of the jacket for the quadrangle or project. The list should be dated and headed "Received from the field." Subsequent receipts of maps or map material from the field or elsewhere should also be listed and dated. Withdrawals of field material should be charged out on the right-hand side of the cover and should be dated.

*Jacket.*—The jacket, indorsed with the list of maps and material received from the field, should remain in the custodian's room in the section of inspection and editing, where it should be available for reference until the map is ready for approval and transmission for advance-sheet photolithography. From the time the map is made available for editing, by jacket indorsement "On editing docket" (see p. 321), until the map is finally engraved and printed, the map and its necessary accompanying sheets must be transmitted in the jacket. Each transmission should be suitably indorsed on the jacket and dated, the jacket thus providing a complete record of the progress of the map through all its stages, beginning with the receipt of the original material from the field and ending with the final publication of the map.

*Progress book, field mapping.*—A progress book showing the areas mapped to date throughout the United States is filed in the office of the chief topographic engineer and should be kept current by the section of inspection and editing. The progress book consists of a series of sectional maps of the United States printed on a uniform scale of 1:500,000, on which the names and quadrangle limits of published maps and the reserved names and quadrangle limits for future work are indicated. The maps that have been published in final form should be shown by a line underscored below the name of the quadrangle. The areas covered by topographic mapping during successive fiscal years should be distinguished by flat tints of distinctive colors, and the areas covered by new mapping should be entered in the progress book at the middle of each month from data supplied on the monthly field reports.

*Authority for quadrangle names.*—The published and reserved names as shown in the progress book of field mapping are the only authorized quadrangle names to be used in connection with the standard topographic mapping of regular quadrangle areas, whether used for planning field work, for making estimates, or for field or office cost keeping or reports.

If a named quadrangle, whatever its size, is to be subdivided into four quarters which have not been or for reasons of expediency are



not to be provisionally named, the four quarters should be designated Nos. 1, 2, 3, and 4, the numbering progressing in a counter-clockwise direction. For example, the four 15' quadrangles within the Riverside 30' quadrangle would be designated "Riverside No. 1," "Riverside No. 2," "Riverside No. 3," and "Riverside No. 4" for the north-east, northwest, southwest, and southeast quarters, respectively.

Where a reserved quadrangle name, after the field survey, is found to be inappropriate or incorrect or can be replaced by a more suitable name the change can be authorized only by a special letter signed by the chief topographic engineer. (See "Changes in names," p.304.) Changes in quadrangle names should be promptly indicated in the progress book of field mapping and in all other current office and field records.

*Progress book, inspection and editing.*—A progress book should be kept in the section of inspection and editing showing in condensed tabular form the office progress of each topographic map and project from the receipt of the field sheets to the final publication of the map. The names of quadrangles and projects should be entered in the book in the order in which they are received from the field or elsewhere, and the finding list should be an alphabetic index that is kept current by including each new topographic map that is received for office work. Entries in the book should be made on the day the information becomes effective.

The purpose of this book is to afford ready reference to office progress on any topographic map and to supply a means of locating the map itself when needed. The list also serves as a check against undue delay in the inking or other completion of the office work on maps and as a guide in the preparation of the annual engraving docket.

*Annual summary of field work.*—An annual summary of topographic field work, including control, for the fiscal year should be prepared in the section of inspection and editing. The data listed should be such as are needed for the annual report of the director, the monthly report of the chief topographic engineer to the director, and such monthly reports to cooperating officials as are currently required. The summary should be kept by States and separate cooperative State or other appropriations. The data should be added to the summary by months and directly from the monthly field reports as soon as received. Quadrangles and projects should be indicated as "completed" when so reported from the field.

The total area in square miles reported for each completed quadrangle should be checked with the figure given in the standard tables, and in case of a difference the tabular figure should be used. Large differences should be subject to correspondence or review when the map involved reaches the office.

*Monthly office report routine.*—Promptness in the submission of reports is necessary because of the following monthly office routine: (a) Check up to insure a 30-day report from each employee; (b) assignment of cost charges by division and section chiefs against each piece of work by each employee; (c) entry of field data in the annual summary of field work (see p. 276); (d) entry of field and office data in the monthly summary of completed quadrangles (or projects) and in the inking progress book; (e) compilation of data for the report of the chief topographic engineer to the director, rendered on the 8th of each month; (f) compilation of sheet and salary charges for submission to the section of accounts on the 10th of each month.

*Annual report.*—The annual report of the work of the topographic branch (director's annual report) should be prepared in the section of inspection and editing. Chiefs of sections and others responsible for information needed in the annual report should forward such data to the chief of the section of inspection and editing as soon after July 1 as practicable.

The chief of the section of inspection and editing should also prepare and forward to the editor of texts a summary for the work of the section of inspection and editing reported under "Work on publications."

## INKING OF TOPOGRAPHIC FIELD SHEETS

### GENERAL INSTRUCTIONS

*Reference to field instructions.*—The inking of topographic maps should be done with as full an understanding of the instructions for field work as is essential for a proper interpretation of the penciled copy. Topographers inking their own field sheets will obviously have this knowledge, but an inker who is not himself responsible for the field mapping (either as author or as party chief) should familiarize himself with as much of the instructions for field work (see pp. 226–272) as may be necessary to interpret the penciled copy properly. For this purpose many cross references are given in the instructions that follow for the inking of the cultural, drainage, and relief features.

*Character.*—In inking field sheets that are to serve as copy for the engraver the topographer or draftsman should first ascertain the scale of final publication and then do his inking in accordance with that scale. He should bear in mind that most manuscript maps are to be reduced and that due allowance must be made in the inking for the reduced size of the final map. He should also remember that all drawings are to be transferred to the copper plates by photographic processes and that it is important that all lines, whatever their color, shall be so inked as to photograph with distinctness. The topographer should execute his inking with neatness and exactness, so that

there may be no doubt as to the placing and meaning of the symbols and lines, and he should aim to give the drafting such quality and clearness that it will enable the engraver to work with rapidity and certainty; but inasmuch as anything beyond that is superfluous, he should beware of wasting time and effort on artistic effects or excessive refinement.

Occasionally more detail is mapped than can be legibly engraved and printed either on the same scale or on a reduced scale. When areas of unusual congestion are reached in the course of inking the topographer or draftsman should seek instructions with a view toward possible generalization or even omission, in order that the engraver may have copy that can be readily understood and legibly reproduced. Where, however, there is unavoidable heavy culture, detailed contouring, or close register between any of the three colors used, no refinement either in the penciling or in the inking can be regarded as excessive. In congested places, therefore, no more lines should be inked than are absolutely necessary for the guidance of the engraver, and the copy should be left as open as the character of the topography will permit. If, however, the inker is unable to furnish the required clear copy in the congested place, he should seek advice before attempting the inking and thus assist rather than retard the completion of the legible copy the engraver must have.

*Consultation with section of inspection and editing.*—Topographic engineers and others engaged in the office preparation of topographic maps for reproduction or other transmission are expected to consult freely with the members of the section of inspection and editing whenever any doubtful points arise and to follow their advice. Every effort should be made to have the map and all accompanying data in as complete and perfect shape as possible when submitted to the section of inspection and editing. Questions of a purely editorial nature, such as a matter needing correspondence or administrative decision, should be left for editorial attention, but data giving all the essential facts should accompany the map.

*Certain maps twice inked.*—Cooperative agreements and other demands occasionally require that certain field surveys or parts thereof shall carry more detail than is to be reproduced save on advance-sheet photolithographs. For example, a city may be surveyed on a large scale, and the resulting map may be lithographed as an advance sheet on the same scale, and later the map may be redrawn on a smaller scale as copy for the usual engraved reproduction; or an area may be surveyed and the map lithographed for special use with a small contour interval and afterward engraved and published with a larger contour interval; or certain areas or strips may be surveyed on a larger scale than is usual in order to provide advance photolithographs of maps—as, for example, for highway



projects—with provision for redrawing the maps on a reduced scale as copy for engraved reproduction. In these cases the field work should be executed in a detail commensurate with that called for by the special-purpose larger-scale survey, and the less detailed copy for final publication should be prepared by redrafting the same map after it has been reduced to the usual scale that is used as copy for engraving. For this redrawing it is customary to reduce the map by photolithography, print it in light blue on drawing paper, and redraw only such detail as is called for by the reduced scale of publication.

It is sometimes desirable to use a previously published map on a large scale as part copy for a new map on a smaller scale. In such cases the larger-scale published map should be reduced by photolithography to the scale of the new map, printed in light blue on drawing paper, and redrawn with its detail appropriately expressed for the smaller-scale reproduction. An example of the need for redrafting a published map is afforded by the survey of a 30' quadrangle, one quarter of which was mapped on a scale of 1:48,000, for publication on a scale of 1:62,500, and it is found desirable to redraw the map on the reduced scale of 1:96,000 (the field scale for the survey of the 30' quadrangle) in order that the greater amount of detailed expression used in the larger-scale survey may be generalized in redrafting and made to conform to the treatment used in the survey of the other parts of the 30' quadrangle.

*Inks.*—The inks that are used must be the best obtainable to meet the office requirements. The important specifications are that the ink will permit a clear photolithographic reproduction, flow freely from the pen, and not spread or afterward smear as a result of any ordinary handling of the map. The following colors are issued: Black, a prepared waterproof liquid ink, in small bottles, to be used directly from the bottle; Prussian blue, burnt sienna, red, and Hooker's green paints, in small tubes, to be mixed in small bottles (furnished by the Geological Survey) in about the proportion of three parts of water to one part of the tube color, to which are added a few small glass beads to facilitate mixing when shaken.

*Colors.*—The field sheets should be inked in the three standard colors used in printing the map—black for the cultural features, blue for the drainage features, and brown for the relief features.

The use of red is reserved chiefly for the inking of certain data that are not to be engraved yet should be inked in order that they may become permanent office records and may appear upon the advance sheets. An exception is made for land lines, which will be inked in red (engraved in black) in order that the engraver may more readily distinguish them from road lines, projection lines, or other lines that may be on or near the section lines.



The use of green is reserved for exceptional needs, such as for showing a second projection which is based on another horizontal datum and for showing corrections where erasures on the original are not desirable.

*Sequence of inking.*—Unless special reasons demand otherwise, the features on the map should be inked in the following order: (1) Culture, (2) drainage, (3) elevations, (4) contouring, (5) lettering.

*Precautions before inking maps.*—Where woodland outlines are carried in pencil on the final field sheets the field woodland tracings should be verified for completeness before the inking of the topography obliterates the woodland copy. Where an elevation tracing has been made or is required (see "Elevation tracing," p. 241) the tracing should be compared with the final field sheets to insure that all necessary elevations have been traced before the inking and handling of the map render the faint pencil figures illegible. The final field sheets should also be carefully examined for names or road-classification data that may have been faintly lettered on them and inadvertently overlooked in making up the field name or road-classification sheets.

*Inking projection lines.*—In inking projections on topographic maps the penciled projection should be inked even though the paper has changed. The projection should not be corrected to agree with the tabular figures, nor should the quadrangle corners be connected by meridional straight lines in order to force a joining between the two half-sheet projections. If the projections do not join at the half-sheet line, the discrepancy, if appreciable, should be taken care of in the photolithography, if for an advance sheet, and by adjustment in small blocks, if for transfer to copper.

*Over-edge inking.*—All over-edge topography should be inked that represents (a) an unmapped area (see "Adjoining unmapped areas, p. 227); (b) an area previously mapped on a smaller scale; (c) a correction to previous work that was mapped on the same scale (see "Joining previous work," p. 227); (d) an important correction to previous work on a larger scale. Over-edge topography on special large-scale military maps should not be inked unless inking is requested. The over-edge topography described under (a) and (b) should appear on the advance sheets, but that described under (c) and (d) will be wiped off the negatives and will not appear on the advance sheets.

*Symbols.*—The symbols used on the topographic maps of the United States Geological Survey conform to the "Standard symbols" as adopted by the Federal Board of Surveys and Maps and prescribed for use by all map-making bureaus of the Government. (See pls. 18–23.) As many of the symbols in the standard set are not used at present by the Geological Survey, none should be used on manuscript sheets unless they have been approved for Geological

Survey use. All topographic engineers are expected to be familiar with the symbols that are in current use by the Geological Survey.

#### SUGGESTIONS FOR INKING

The preparation of field sheets for reproduction differs somewhat from general drafting. Because of the relatively small scale upon which quadrangle maps are drawn their inking is essentially free-hand drafting, and for this reason lettering pens of several degrees of fineness are employed almost exclusively.

*Black ink.*—A waterproof black ink only is approved for regular use. Skilled draftsmen may draw better lines with a nonwaterproof black ink, especially on a poor surface, but the considerable handling to which the drawing is subjected before it is engraved or otherwise reproduced is so likely to smear the congested places in the inking that the use of a nonwaterproof black ink is not often approved for such use.

*Pens.*—The use of a ruling (right line) pen for the drafting of straight lines is optional. Many draftsmen prefer to draw straight lines with a lettering pen. A ruling pen should be held nearly vertical and not on a slant, and just enough pressure should be exerted to keep the pen in contact with the paper. If the ink at the lower end of the pen dries slightly so that it will not flow, pinching the pen will often start the ink. A ruling pen should be kept sharp and clean, and its points should be ground to the same length. If ink will not flow freely from a lettering pen holding it in the blaze of a match for a second will burn off any oil that may have adhered to it from handling. All pens should be thoroughly cleaned before putting away.

*Mixing water colors.*—Two methods of preparing water-color paints for use as inks may be used—dissolving the paint with a wet brush and transferring it to the pen, or mixing a quantity of the paint in a bottle. The latter method is in more general use, and the mixture is prepared as described below: Squeeze the paint from the tube into a small wide-mouthed bottle in which four or five glass beads have been placed. Add 3 parts of warm water to 1 part of the paint and let it mix, shaking the bottle and the beads to facilitate the mixing. If the mixture is too thick it will not flow freely from the pen and if it is too thin the drafted lines will lack depth of color. To obtain the best mixture, test it as follows: Dip a lettering pen deep in the mixture and withdraw it. If the paint swells out in globular form it is too thick, and a few drops of water should be added; this should be repeated until the test shows the ink fairly flat on the pen. The bottle should be frequently shaken during the course of inking, in order to keep the paint in an evenly mixed suspension. A few drops of carbolic acid will prevent the mixture from souring in warm weather.

*Inking roads.*—Roads may be inked with a ruling pen but are best inked with a fine lettering pen, used against a small beveled triangle. A uniform width of road is dependent upon the skill of the inker, as the two sides of the road are inked separately. Curves may be shown as a succession of short tangents or inked freehand.

*Inking railroads.*—Where sidings, spurs, and yard tracks are to be inked these tracks and the parallel main track or tracks opposite them should be inked first in fine lines, and then the main tracks on each end inked in slightly heavier lines. On the engraved plates the main track as well as the siding is cut in a fine line.

*Inking drainage and contours.*—The drainage or contours should be inked toward the draftsman, the position of the map being shifted from time to time to make this possible, and all lines within convenient reach should be inked before the position is changed. To obtain the finest and sharpest lines for the intermediate contours a finer pen may be used than that used for the inking of the heavy contours. Contour figures should be made in a single-stroke style rather than shaded.

*Erasures.*—In making an erasure a knife must not be used except to remove the ink that is on the surface of the paper. After this has been done the erasure should be completed with a fine sand and a plain rubber eraser, only light pressure being exerted and the surface afterward burnished with a smooth bone handle. If the paper has become soft and pulpy by erasures, an inking surface may be restored by brushing one or two coats of collodion over the area affected.

#### TRANSFERRING

*Celluloid transfers.*—If a map section of considerable size needs to be transferred to the main map and only slight adjustment is necessary, the work can often be advantageously done by means of a celluloid transfer. A celluloid transfer may be obtained on requisition and consists of a photolithographic reproduction of the map printed in a graphite ink on the under side of a sheet of transparent celluloid.

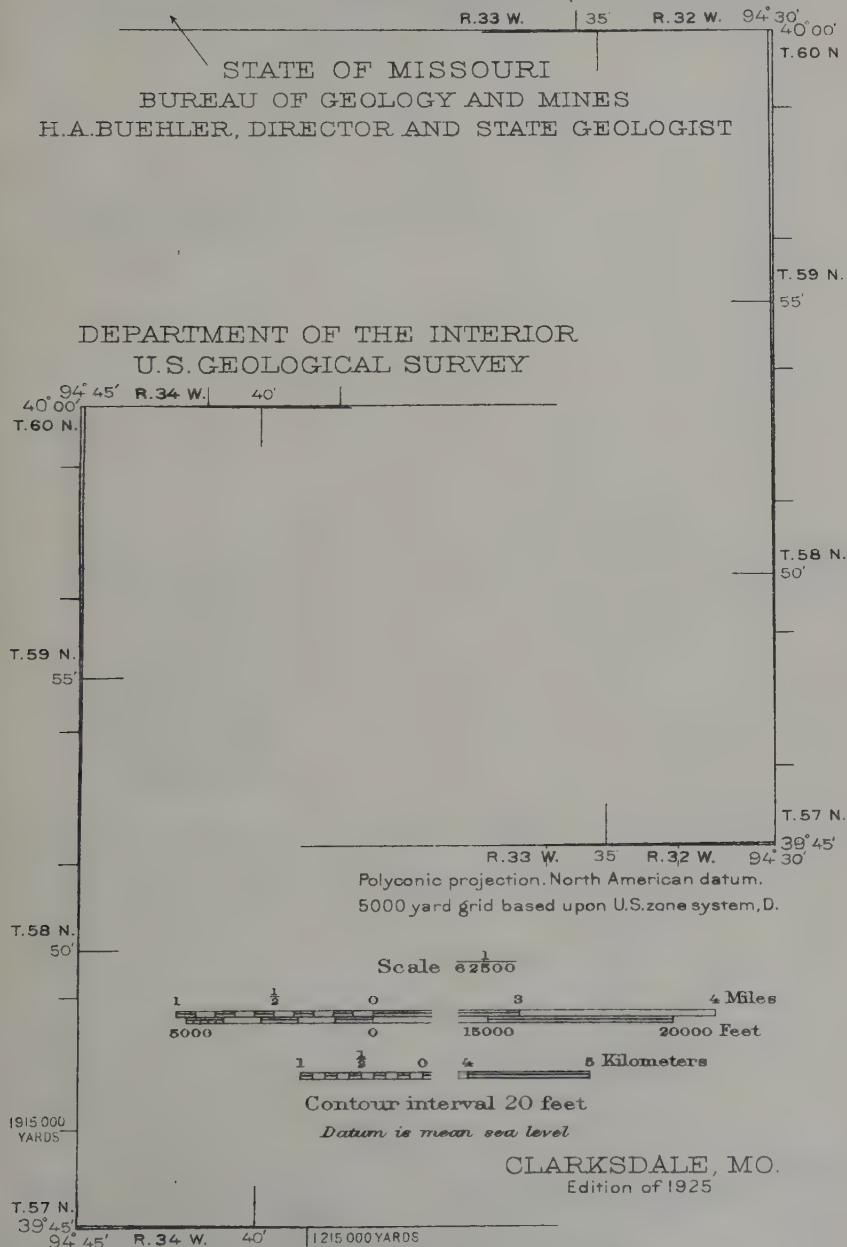
A celluloid transfer should be used within a few days, as the ink may dry, but if used at once the excess of graphite should be gently rubbed off until a trial transfer gives a sharp line. The celluloid transfer should be adjusted in place, printed side down, and burnished with a half round smooth piece of steel and moved as often as may be needed in the adjustment. Any graphite remaining can be easily erased after inking.

*Transfer by tracing.*—A section of a map, such as a traverse line, may be transferred to the main sheet by tracing on thin paper only the critical or salient parts and omitting lines or data that are close together, because these are more accurately added free-hand afterward; then slipping a piece of transfer paper, carbon side down,

MISSOURI  
CLARKSDALE QUADRANGLE

STATE OF MISSOURI  
BUREAU OF GEOLOGY AND MINES  
H.A.BUEHLER, DIRECTOR AND STATE GEOLOGIST

DEPARTMENT OF THE INTERIOR  
U.S.GEOLOGICAL SURVEY







# PLAN AND PROFILE OF CLEARWATER RIVER, IDAHO

SHEET A

DEPARTMENT OF THE INTERIOR  
U. S. GEOLOGICAL SURVEY

Subject to adjustment

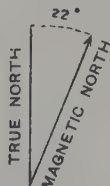
(7 plan sheets, 7 profile sheets)

Printed in 1926

DIAGRAM OF TOWNSHIP

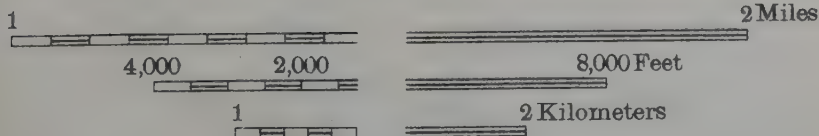
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Topography by R. W. Burchard  
Surveyed in 1924



APPROXIMATE MEAN  
DECLINATION, 1924

Scale  $\frac{1}{81,680}$



Contour interval on land 20 feet

Contour interval on river surface 5 feet

Datum is mean sea level

MARGINAL LETTERING FOR RIVER-SURVEY SHEETS



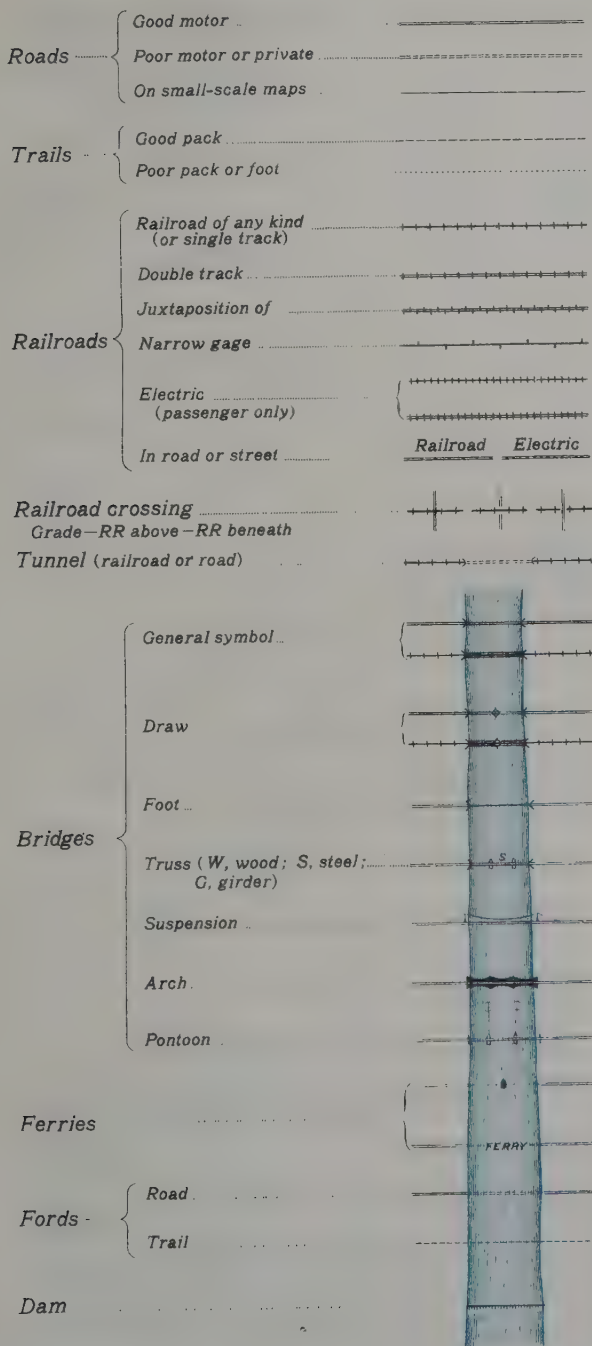


REPRODUCTION OF PART OF A TOPOGRAPHIC MAP





## WORKS AND STRUCTURES



STANDARD SYMBOLS FOR USE ON TOPOGRAPHIC MAPS

The use of colors is optional



## WORKS AND STRUCTURES—CONTINUED


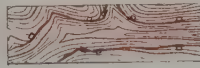
Telegraph or telephone lines ..... T T T T T T T T




Telephone line  
(optional for Forest Service) ..... 

Power-transmission line ..... \* \* \* \* \*



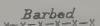


Buildings in general ..... 

Railroad station of any kind ..... + + + + +

Church ..... Church (optional for nautical charts) ..... Schoolhouse ..... Gemetry ..... Ruins ..... Cliff dwellings ..... 

City, town, or village (small-scale maps)	{	Capital	
		County seat	
		Other towns	

City, town, or village (generalized) .....  

Fences	{	Fence of any kind (or board fence)	.....
		Stone	..... 
		Worm	..... 
		Wire	.....  
		Hedge	..... 

Mine or quarry of any kind (or open cut) ..... Prospect ..... Shaft ..... 

Mine tunnel	{	Opening	.....
		Showing direction	..... 

Oil or gas wells ..... 

STANDARD SYMBOLS FOR USE ON TOPOGRAPHIC MAPS

The use of colors is optional





## WORKS AND STRUCTURES—CONTINUED

Windmill .....

Tanks .....

Coke ovens .....

Canal or ditch .....

Canal abandoned .....

Canal lock (point upstream) .....

Canal lock (large scale) .....

Aqueduct or water pipe .....

Aqueduct tunnel .....

## BOUNDARIES, MARKS, AND MONUMENTS

National, State, or Province .....

County .....

Civil township, district,  
precinct, or barrio .....

Reservation .....

Land-grant .....

City, village, or borough .....

Cemetery, small park, etc. ....

Township, section, and quarter-section  
lines (any one for township line alone, any  
two for township and section lines) .....

Township and section corners recovered .....

Boundary monument .....

Triangulation point or transit-traverse station .....

Permanent bench mark (and elevation) .....

Supplementary bench mark (and elevation) .....

U. S. mineral or location monument .....

## STANDARD SYMBOLS FOR USE ON TOPOGRAPHIC MAPS

The use of colors is optional





## DRAINAGE

*Streams in general* . . . . . 

*Intermittent streams* . . . . . 

*Probable drainage, unsurveyed* . . . . . 

*Lake or pond in general*  
(with or without tint, water lining, etc.) . . . . . 

*Salt pond (broken shore line if intermittent)* . . . . . 

*Intermittent lake or pond* . . . . . 

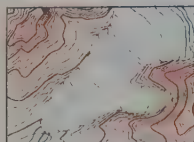
*Spring* . . . . . 

*Wells or water tanks* . . . . . 

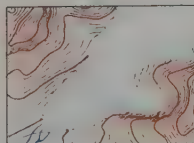
*Falls and rapids* . . . . . 

*Glaciers* . . . . . 


*Contours*  
(or as below)



*Form lines showing flow*



## AIDS TO NAVIGATION

*Lighthouse and beacon* . . . . . 

## STANDARD SYMBOLS FOR USE ON TOPOGRAPHIC MAPS

The use of colors is optional





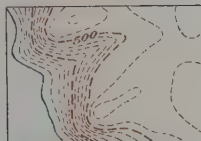
## RELIEF

(Shown by contours, form lines, hachures, or shading as desired)

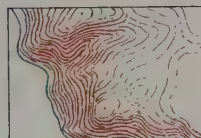
Contours (blue if under water)



Contours (approximate only)



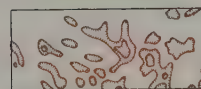
Form-lines (no definite interval)



Hachures



Depression contours



Guts



Fills



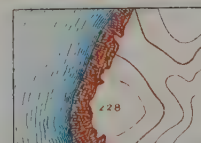
Mine dump

Tailings

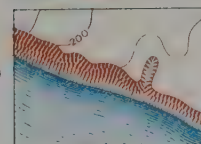


Bluffs

Rocky (or use contours)



Other than rocky (or use contours)



Sand and sand dunes


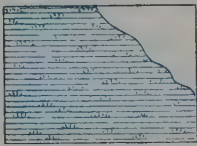


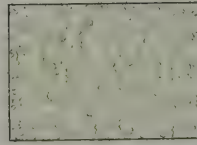

Wash

Levee





## LAND CLASSIFICATION

Marsh	Marsh in general	
	Optional for nautical charts	
	Cypress swamp	
Woodland of any kind (or as shown below)		Flat green tint
Woodland of any kind (or broad-leaved trees)		
Woodland, impenetrable		
Pine (or narrow-leaved trees)		

## LETTERING

*Names of natural land features, vertical lettering**Names of water features, slanting lettering*

## STANDARD SYMBOLS FOR USE ON TOPOGRAPHIC MAPS

The use of colors is optional





between the tracing and the map, and going over the traced lines again with a fine metal point or a hard pencil. Transfer paper may be made by blackening one side of thin tracing paper with a soft pencil and rubbing the blackened surface down to a smooth finish with blotting paper.

#### PASTING

*Preparing a patch.*—A separate original section of a topographic map that needs no adjustment may be transferred to the main map by pasting it on as a patch in its true position. Indicate with a light pencil line the limits of the part that is to be pasted. The map section should then be separated from the linen filling of the double-mounted drawing paper. To do this lay the section of the map face down on a desk or other hard clean surface and start the separation at one corner with the finger nail. As the peeling progresses follow up with a triangle weighted down by hand so that the face of the map will lie flat and be in contact with the desk or other surface at the point where the peeling is taking place. If this method is followed the map section will not be torn or buckled. When the map section has been peeled trim it along the pasting limits previously indicated by a pencil line and bevel the edge for a width of a quarter to half an inch. To bevel the edge place the patch face down on a cutting board, cut the bevel with a sharp knife and smooth it off with fine sandpaper. Do not cut along a projection line, and so far as practicable, avoid cutting along a road or land line.

*Pasting the patch.*—Place the map section in position on the main map and indicate register marks so that it can be again placed in identically the same position. Rubber cement, thinned with pure benzine or refined benzol, may be used as the adhesive and has the advantage of slow drying and ease of removal at any later time if needed. Coat the area of the main map to which the patch is to be applied and the back of the patch with at least three paintings of the rubber cement and allow each coat to dry before another is added. Do not apply the patch until the last coat of cement is dry. To affix the patch place one set of register marks in position, holding the rest of the patch away from the map, while strips of paper are placed between it and the map in such a manner as to be removable after the other marks have been brought into register. When the patch is in a satisfactory position, withdraw the paper strips and burnish the patch into a good contact, paying particular attention to the edges. Superfluous cement can be rubbed off with the fingers or with a soft rubber eraser. If it is desired to remove the patch, start the peeling at one corner with a knife blade and gradually pry it loose. Before replacing the patch the old cement should be removed; then proceed as before.

## INKING OF CULTURAL FEATURES

Cultural features should be inked in black except as some other color is specified under the headings below. Cultural features that are added for sheet information only and are not to be engraved, or features for which the engraving may be in doubt, may be inked in red. For general instructions covering the inking of all map features see pages 277-283.

The field instructions for the mapping of cultural features (pp. 229-242) are to be regarded as supplemental information needed for the proper interpretation of the following instructions for the inking of cultural features, and for this reason frequent cross references are given.

*Roads, country.*—Roads should be inked by solid double parallel lines or by dashed double parallel lines, according to the penciled copy furnished in compliance with instructions for field work. (See "Roads," p. 229.)

Roads are engraved to standard gages for each publication scale, unless the drafted copy calls for a wider gage for certain roads, such as highways or avenues of unusual width, or unless on large-scale maps special engraving instructions are given to cut all roads to widths as drawn. Roads should, therefore, with these exceptions, be inked of uniform width and with as fine lines as will remain firm and unbroken. As it is impracticable, however, especially on paper that has been rubbed in the field, to draft roads of the fineness and narrowness of engraved roads, even when these are enlarged to field scale, the topographer should ink the roads a little wider than the standard gage; a width of 75 feet (center measurement) when plotted on a scale of 1 : 48,000 (approximately 0.02 inch) may be taken as a guide. If a narrower width is attempted the lines are likely to run together when reduced and transferred to the copper plates, and they may even run together on the drawing. A clear space in the middle of the road symbol is essential to furnish good road copy for the engraver.

In inking the dashed double line road symbol care should be taken to maintain a uniform length of dashes, a uniform width between dashed lines, but not too close spacing between the successive pairs of dashes, and a uniform weight of individual lines, and the overlapping of either of the double dashed lines beyond the other should be avoided.

Where the middle of a road follows a projection line bordering an unmapped quadrangle, the road should be shown as entirely within or entirely without the mapped quadrangle so far as practicable. A space should be left between a house and the end of a road leading to it.

*Streets, city.*—City streets should be inked only by the best draftsmen; and all street lines should be drawn fine and finished off neatly

at the corners, a reading glass being used for this purpose where necessary. Any overrun of the inking into the open space inside the road symbol should be erased so as to leave clear copy. Cities and villages, where combined with contours and stream courses, present difficult copy for the engraver at best, and every endeavor should be made to keep the road lines fine and the copy as open as circumstances may warrant.

*Buildings in general.*—The houses on the manuscript sheet should be inked square and of uniform size and should be drafted by outlining an open inked square, with sharp corners, and afterward filling in. If houses are inked too small it becomes difficult to make them square, and unless they are inked square and sharp their identification as houses becomes uncertain even on the original drawing. The following approximate dimensions may be taken as standard for the inking of the conventional country-house symbol on the field scales specified: 1 : 96,000, 150 feet square; 1 : 48,000, 75 feet; 1 : 31,680, 50 feet; 1 : 24,000, 25 feet. These dimensions, however, should be increased or decreased in congested places, if the legibility is correspondingly improved. Large structures which, plotted to scale, exceed the size of the ordinary symbol should be shown with their individual plan outlines.

*Use of blocks.*—If the buildings and blocks appear to have been penciled in conformity with the field instructions (see p. 231) they should be inked as penciled; but if they appear to be penciled closer together than the field specifications call for they should be inked in blocks.

*Business and residence blocks.*—Residence blocks (see p. 231) should be inked distinctly narrower than business blocks, but this distinction should be made in the inking only where it has been made in the field work and where the penciling or other copy is clear.

*Churches and schoolhouses.*—The symbols for churches and schoolhouses are described under field instructions. (See p. 232.) The house part of either symbol should be inked the same size as called for under "Buildings in general" (p. 231). The flag may fly on either side of the pole, and in congested places the inked pole may be lengthened if the symbol is thereby made more legible.

*Railroads.*—Before a railroad (see p. 232) is inked the penciled copy should be examined to determine its points of tangent and points of curve and then inked in such a way as to bring out a characteristic railroad alinement. The distinction between railroads of the steam type and electric trolley lines is given in the field instructions. For the former the cross ties are spaced twice as far apart as for the latter. Where the distinction is in doubt the wider spacing should be used, as the intermediate ties can easily be inserted if found necessary.



In railroad yards, parallel spur tracks, etc., only as many tracks should be inked as can be legibly engraved on the publication scale, as too many tracks make difficult inking, illegible advance sheets, and impracticable engraving. Where switches and sidings are inked alongside single tracks both the main track and the side tracks should be inked in finer lines than the main track elsewhere; and these fine lines should be inked first and the extension of the main track inked afterward in a heavier line, to make clearer copy for engraving.

The penciled copy for railroads in juxtaposition should be checked before being followed.

Railroads and electric trolley lines that are within roadways should be shown only by the fine cross-tie lines at right angles to the road symbol, to the full width of the road as inked and with the spacing used in the corresponding regular symbols.

*Tramways.*—Tramways should be inked in the broad-spaced railroad symbol. Aerial tramways should be inked in a broken line, and the name should be added where there is space.

*Railroad crossings.*—In inking crossings of railroads and roads (see p. 232) a distinction should be made between a grade crossing and a crossing not on grade. Where the road passes under the railroad the road symbol should be broken and the railroad symbol continuous, and where the railroad passes under the road the railroad symbol should be broken and the road symbol continuous.

*Railroad station buildings.*—A railroad-station symbol (see p. 232) should not be inked unless there is a building on the ground. The symbol for a railroad station should be carried across the track only where the location of the train stop would be otherwise uncertain. The railroad-station symbol should not be used in country regions where the presence of a crossroad or the position of the lettering sufficiently locates the train stop, and the use of the symbol should be confined chiefly to small towns and other places where the lettering can not be placed near the position of the train stop and where this position can not be inferred from the map.

*Bridges.*—The bridge symbol (see p. 232) should be inked only where there is clear penciled copy or where definite information exists that there is a bridge of the importance specified in the field instructions. The symbol should be omitted in areas of heavy culture and wherever its presence would interfere with the legibility of the map on the publication scale. Ordinary railroad bridges and trestles should not be shown. Drawbridges on roads and railroads should be shown by a separate symbol. Bridge ends for viaducts should in general be omitted.

*Ferries.*—Ferries (see p. 233) should be shown by the symbol, with the boat pointing upstream, or the word "FERRY," according to

the available space on the map. The name of the ferry should be used in lieu of the word alone where the name is well recognized locally.

*Fords.*—(See field instructions, p. 233.)

*Trails.*—Poor pack trails and all foot trails should be inked in the dot symbol; good pack trails in the dashed-line symbol. Where the field penciled copy or classification is uncertain use the dashed symbol. (See p. 233.)

*Steamboat routes.*—(See field instructions, p. 233.)

*Canals and ditches.*—Canals and ditches should be inked in blue. (See p. 233.) Short ditches that have been penciled on the field sheets in the course of survey and have not been erased should not be inked if they appear to be laterals rather than main feeders. Abandoned canals should be inked if of the importance called for in the field instructions.

*Canal locks.*—The symbol for canal locks should be inked only so far as it can be legibly engraved on the publication scale, and the upper and lower gates should be separately inked only where both gates can be legibly shown. If the penciled copy is not clear inquiry should be made before the inking is completed. (See p. 234.)

*Aqueducts and pipe lines.*—(See field instructions, p. 234.)

*Power-transmission lines.*—Power lines may be inked in black, but if they are in close contact with other cultural features they should be inked in red for clearer recognition. Power lines should not be inked in sections of heavy culture. (See p. 234.)

*Tunnels.*—Railroad or road tunnels should be inked in black, aqueduct tunnels in blue. (See p. 234.)

*Dams.*—The elevation of the top of a dam should be recorded. The dam should be inked to its mapped length only, and its ends should be represented at identical elevations as shown by the contouring. (See p. 234.)

*Reservoirs.*—Artificial reservoirs surrounded by dams on all sides should not be inclosed by the dam symbol but should be outlined in blue like lakes or ponds; small reservoirs should be further emphasized by a blue wash. (See p. 234.)

*Levees, cuts and fills, mine dumps.*—Levees, cuts and fills, and mine dumps should be inked in brown, and if more have been penciled than appear to be authorized by the field instructions (see p. 234) further instructions should be sought before inking those whose status is uncertain.

*Depression contours.*—(See "Artificial depressions," p. 234.)

*Wharves, piers, jetties, etc.*—Wharves, piers, docks, and similar structures should be inked in black, in outline only, as plotted to scale in the field. A narrow wharf or pier should, however, be represented conventionally by a double line about the width of a

narrow road. Jetties and breakwaters should be inked in single heavy black lines: (See p. 235.)

*Lighthouses, etc.*—Lighthouses and lightships are to be shown by their respective symbols on all maps, whatever the scale.

*Cemeteries.*—The outlines of cemeteries should be inked; the name, if well known, should be shown if there is space; otherwise a cross within the outline or the letters "CEM" alongside. Small private cemeteries should not be shown unless they constitute landmarks in a thinly settled country. (See p. 235.)

*Mines and quarries.*—A careful distinction should be made between the inking of mine symbols in black if to be engraved and in red if intended for sheet information and advance lithographs only. (See p. 235.)

*Oil and gas wells.*—The small circle inked in black, should be used to represent an oil or gas well. If the oil or gas field only is shown the outline should be inked by dashed lines in black. (See p. 235.)

*Furnaces, smelters, and coke ovens.*—A furnace or smelter should be inked in black, like any other building. Only coke ovens that are to be engraved should be inked, in black. (See pp. 235–236.)

*Civil boundaries.*—Civil boundaries (see p. 236) should be verified before inking as a precaution against gross errors in the interpretation of penciled field copy, as erasure of an erroneous inked boundary line usually involves erasure of adjacent topography also. Where civil boundaries of different classes coincide for a distance the symbol of the major subdivision should take precedence, but in particularly complicated regions, especially among minor subdivisions, it may sometimes be necessary for the sake of clearness to depart from this rule.

Where it is obvious that a civil boundary follows a stream or road for a short distance, the boundary symbol may be omitted to avoid confusion. In some places, however, clearness may be increased by placing the boundary symbol immediately alongside of the stream or road in red.

For further detailed instructions, given separately by names of boundaries, see pages 322–328; for civil townships and other subdivisions see also page 237.

*Boundary monuments.*—National, State, and national park boundary monuments, with designating numbers alongside, should be inked in black. Boundary monuments on other lines, with designating numbers if obtainable, should be inked in red. The open block indicating the monument should be oriented with the line it marks.

*County subdivisions.*—If in doubt whether to ink boundary lines showing subdivisions of the county, read carefully the field instructions (p. 237) and then look through the field material for comment from the field engineers as to the local status of the lines. In those



parts of the country or in those States where the Geological Survey has not in the past shown such subdivisions, each new map must be fully considered before a decision is reached, and under such conditions the inker should seek office advice.

*Public-land lines.*—All public-land survey lines (see p. 238) should be inked in red so that they may not be mistaken for other cultural features; section lines should be inked in fine lines and township lines distinctly heavier. The adjustment of land lines should be checked by someone other than the compiler before they are inked; and the need for this examination increases with the proportion of the land net taken from the plats and notes alone rather than from the connection of found corners.

Only those township and section lines and parts thereof that have been surveyed and approved by the General Land Office, are not under suspension, and are indicated on the land plats by solid lines should be inked on Geological Survey topographic maps. The fractional distances for less than section lengths are usually found on the land plats, and such distances afford the means for plotting fractional land lines on maps. Land lines broken at water surfaces on account of shore meanders should in general be broken as shown on the plats. Meander lines should not be plotted or inked.

*Found corners.*—Public-land corners that have been found in the course of field work and are clearly indicated as such on the field sheets should be inked in the symbol for found land corners. In inking land lines adjacent to found land corners a short space should be left clear on all sides of the symbol so that it can be readily recognized.

*Township and range numbers.*—Township and range numbers should be placed along the margin of the map opposite the middle of each township, the township numbers along the right and left and the range numbers along the upper and lower margins. If the numbering is irregular, however, the numbers should be placed within the townships. On large-scale maps that cover only two or three townships or fractions thereof the township and range numbers should be placed opposite the lines bounding the townships.

Numbers and names of base lines and principal meridians should be shown.

*Section numbers.*—On the 1:62,500 scale and all larger scales sections within townships should be numbered.

*United States location and mineral monuments.*—Each United States location and mineral monument (see p. 240) should be inked by a solid triangle and designated by letters and official number, preferably at the right of the symbol, as "USLM 2," "USMM 237."

*Triangulation points and transit-traverse stations.*—Only those triangulation points and transit-traverse stations that have been used in



the course of topographic mapping (see p. 240) should be inked or shown on Geological Survey maps, and these stations should be inked by the triangle and dot symbol. No triangle should be inked until the identity of the station has been established and its plotting checked, and this check should precede the inking of any cultural features directly adjacent to the station.

The names of triangulation points and the numbers of transit-traverse stations should not be added to the inked maps prior to the control examination.

*Level bench marks.*—For bench marks (see p. 240) all letters "BM," all crosses (permanent and supplementary), and all figures of elevation should be inked in black. The cross should be of the style used on engraved maps but with the lines of the cross inked fine and 0.2 inch in length, or longer if necessary for the better identification of its location. All bench-mark figures of elevation should be upright. All bench marks that have been plotted on the field sheets should be inked on the final sheets, except those in areas of heavy culture, but the figures for such supplementary bench marks as do not represent good engineering benches will be changed to red in the control examination.

*Vertical-angle bench marks.*—Vertical-angle bench marks (see p. 240) should be indicated in the same way as standard permanent bench marks, except that the letters "VA" will be added on the same line and in front of the letters "BM," if the bench mark is on or near a road or other route of travel and therefore liable to be mistaken for a standard permanent bench mark.

*Control points adjacent to cultural features.*—In inking culture that is adjacent to control points (see p. 241) care should be taken to maintain the correct relative position of the control and the cultural features.

*Useful elevations.*—All useful elevations as defined on page 241 should be inked in black in slanting block figures. The elevations selected for engraving will be determined in the editing of the map and will be printed in black on the published maps. On maps that are to be reproduced by engraving no elevations should be inked in red. On maps that are to be reproduced by photolithography alone special instructions will govern individual cases, according to the arrangement of the copy.

*Location crosses.*—Where the location of an important feature is not obvious from the position of the lettering designating it or where figures alone do not clearly indicate the location of a point whose elevation is given, a small location cross may be added in brown and may be engraved on the brown plate.

## INKING OF DRAINAGE FEATURES

If a mixed blue ink is used for inking drainage features it must be thoroughly mixed and dark enough to insure strong photographic value.

*Shore lines in general.*—Shore lines of all waters should be inked in a firm continuous blue line and not broken for wharves, piers, and similar structures that may be built out over the water; such structures should be inked in black. Sea and retaining walls that are but artificially constructed parts of the shore line should be inked in blue.

*Tidal shore lines.*—(See field instructions, p. 242.)

*Use of Coast and Geodetic Survey charts.*—Before coast lines and the adjacent offshore features are inked the penciled copy should be compared with late large-scale Coast and Geodetic Survey charts (see p. 242), and wherever marked differences are found that are not fully explained in the field material or on the information tracing, further inquiry should be made of the author or other competent authority. Coastal features appearing only below the line of mean high water should be omitted from Geological Survey maps.

*Under-water contours.*—Under-water contours should be added to the final drawings of coastal maps if the Coast and Geodetic Survey can supply the necessary data. They should be shown for offshore depths corresponding to the contour interval used on land and should be carried to the limits of the quadrangle or so far as data are available. Additional contours for depths of 5, 10, 20, and 30 feet should be shown where appropriate. Ink in blue.

*Marshes in general.*—Marsh or swamp of any kind (see p. 242) should be inked by the symbol for marsh in general; no distinction should be made between fresh, salt, or other marsh. The outlines of marsh areas should be inked by fine dashed blue lines, but the dashed lines should not be engraved save where they are needed to designate small and but slightly separated areas of marsh that otherwise would be collectively mistaken for large continuous areas or where they are needed to indicate small detached areas that have sharply defined limits but are not clearly outlined by the symbol alone and yet constitute prominent features or landmarks.

*Submerged marsh.*—Areas of submerged marsh (see p. 242) should be indicated by inking grass tufts in blue (no horizontal lines) on the water surface.

*Wooded marsh.*—Wooded marsh (see p. 243) should be inked in blue as marsh and the outline added to the woodland sheet.

*River shore lines.*—The penciled copy for broad rivers (see p. 243) should be carefully examined before inking in order to ascertain whether the shore line shown represents the probable normal stage

of the water. If the appearance of the copy or an attached memorandum in any way indicates or suggests a mapping of the shore at some stage other than the normal, the inker should seek further office instructions before inking the shore line, islands, sand bars, etc. As the normal stage of inland waters is the accepted shore line on Geological Survey maps, no features that are exposed only below that stage of the water should be inked. Water-surface elevations should be inked wherever they can be legibly drafted.

*River banks.*—(See field instructions, p. 243.)

*Sand.*—The sand symbol (see p. 255) should be inked with brown dots of uniform size and spacing. Tidal sand that is exposed below the line of mean high tide or below the line of the normal stage of rivers and lakes should not be inked. The outline of sanded areas should not be inked but shown by a careful inking of the dots.

*Natural lakes.*—If the appearance of the penciled copy or an attached memorandum indicates that the shore line of a lake was mapped at a stage of the water above or below the normal stage, the inker should ask for instructions before inking the shore line. (See p. 243.) The shore line of a large lake whose surface is subject to periodic rise or fall should be that determined on the date of survey; and this date should be lettered on the water surface, with corresponding elevation. The elevation (normal stage) of all other lake or pond water surfaces should be inked wherever the figures are available and can be legibly shown.

*Reservoirs.*—(See field instructions, p. 234.)

*Artificial lakes.*—The elevation of an artificial lake (see p. 243) should be inked, if given, and should represent the stage of water mapped and as controlled by the dam.

*Intermittent and dry lakes.*—Intermittent lakes and ponds, dry salt lakes, and alkali flats (see p. 245) should be inked by the symbol for intermittent lake or pond, a dashed outline with the surface indicated by hatching, in blue.

*Islands.*—The instructions given above for inking tidal shore lines, river shore lines, and lake shore lines should be followed for island shore lines so far as they are pertinent.

*Drainage classification.*—Before streams are inked the draftsman should look over the entire original and also the information sheets and adjoining maps in order that the classification as inked may represent the fullest information at hand. (See p. 244.)

*Perennial streams.*—In general, all perennial streams (see p. 244) except very short stubs and insignificant rills should be inked on maps drawn for publication on a scale of 1:62,500. For maps on larger scales (1:31,680, 1:24,000, etc.) all perennial streams except the smallest rills may be inked, but rills also may be inked where, in



the absence of contour lines defining their channels, they constitute features of topographic importance.

On maps drawn for publication on a scale of 1:125,000 the amount of perennial drainage to be inked should be only slightly less than that for a scale of 1:62,500, the omitted streams being the shorter forks or tributaries whose inking would give a stubby expression to the drainage. For a scale of 1:250,000 much less drainage should be inked than would be represented on a scale of 1:125,000.

Perennial streams should be inked with a solid blue line increasing in strength with the size of the stream but nowhere so broad as to be equivalent to double lines. Care should be taken not to draw streams to the edge of the map with a width that can not properly be continued on the next map. Stream lines should taper off toward the sources of the streams but should remain deep and strong in color to the head. If allowed to become faint the blue will not photograph.

*Intermittent streams.*—On the penciled field sheets all intermittent stream courses (see p. 244) are outlined down to their minuter ramifications, as an aid in contour sketching, but only the larger ones are to be inked and engraved. The general rule should be to ink no intermittent stream that will be less than three-quarters of an inch long on the scale of publication. In the more arid districts a smaller proportion of the intermittent drainage should be inked, and the minimum length should be increased to 2 inches or more, according to scale, as may seem appropriate to the degree of aridity.

It is to be borne in mind that drainage lines are delineated not merely because they indicate water features but because they constitute an important element in the conformation of the land surface and because they afford supplementary information of value in the interpretation of the relief. Whatever the degree of aridity, therefore, it is desirable to show a certain amount of intermittent drainage on the map for the sake of legibility. More especially is this true in delineating intricately sculptured areas, the topography of which in the absence of drainage lines appears chaotic and unintelligible at first glance.

Aggraded flats and valley floors devoid of well-defined stream channels or scars are not properly shown with drainage lines running through them.

Intermittent streams should not be inked up to or close to the divides, as the contours usually suffice to define the location of stream heads.

*Double-lined streams.*—Only those streams should be double-lined whose actual width can thus be shown without exaggeration on the scale of publication. (See p. 244.)

*Disappearing streams.*—Disappearing streams and streams starting from subterranean sources (see p. 245) should be inked to represent



the surface drainage only, and this will be classified as given under the rules for perennial and intermittent streams. On field sheets where the presence of disappearing or reappearing drainage is suggested by the representation of sink holes or other indication, the penciled copy should be carefully examined for possible drainage of this character.

*Springs.*—Springs (see p. 245) should be inked or not according to their importance as stated in field instructions. A walled-in spring should be shown like a well, by a blue circle, but a spring that is a source of a stream should be shown by a blue circle with the outlet stream as plotted.

*Wells and water tanks.*—The symbol for a well or water tank is a small blue circle. (See p. 245.)

*Glaciers.*—The outline of a glacier (see p. 245) should be inked in a dotted blue line and its surface contours in full blue lines.

*Tinting of water bodies.*—Oceans, bays, lakes, ponds, and broad rivers should be tinted blue (blue tints will not photograph) on the manuscript sheets only in places where the copy for engraving would otherwise be ambiguous. If the tint is added after the shore line has been inked, the shore line should be reinked wherever the wash has destroyed or broken the line or so weakened its strength as to render it nonphotographic. As a further guide for the engraver, a deeper blue wash may be added immediately along the shores, islands, rocks, and other features. Bridges and other structures built over the water should not be thus outlined by a darker tint.

#### INKING OF RELIEF FEATURES

Relief features are to be inked in brown.

*Strength of contour lines.*—Contour lines should be inked in firm smooth lines of even strength. For convenience in reading them every fifth or fourth contour should be accentuated (for contour intervals of 1, 5, 10, 20, 40, 50, 100 and 200 feet, every fifth; and for intervals of 25 and 250 feet, every fourth). The accentuation should consist in drawing the lines heavier, rather than in making them broken or dotted. The weight of the accentuated (heavy) contours should make them stand out from the intermediate contours but should not be so excessive as to cause them to dominate the relief. The intermediate (light) contours should be inked in fine lines.

Where the identity of a heavy contour is lost in a band of contours, as in the representation of a cliff, it may be advisable to place contour numbers on one or more adjacent light contours in order that the contouring may be more easily read.

*Sequence of contour inking.*—The heavy contour lines should be inked first and should be finished over considerable areas before the light contours are inked. The heavy contours should be compared with

adjoining bench-mark and other elevation figures as a check on their identification, and identification marks such as contour numbers in light pencil should be placed here and there upon them in order that the correct continuity of the heavy lines may be well established before light contours are inked. The heavy contours should not be dropped at any place save for contour numbers, but the light contours should be omitted on uniform steep slopes and in other places where their inking is not essential and would tend to confuse the copy rather than aid the engraver. Before the intermediate contours between any two successive heavy contours are inked, the penciling should be closely examined to insure that no contours have been dropped or duplicated.

*Uniform steep slopes.*—Where the slope is both steep and uniform only the heavy contours need be inked, as the engraver can interpolate the light lines on the copper plate as readily as the topographer can ink them on his map, and the copy for the engraver is the clearer for their omission. Attempts to fill them in for the mere sake of enhancing the appearance of the manuscript sheet are not permissible.

*Steep slopes that are not uniform.*—Where a slope is steep but not uniform the change in slope is more likely to occur on a light contour than on a heavy contour—for example, with a 20-foot interval the chance of the slope changing at a light contour instead of at a heavy contour is as 5 to 1. Therefore, if the interpolation of the light contours on such slopes is left to the engraver, an erroneous banded effect will result on the engraved map where successive bands of light contours are uniformly spaced between heavy contours that are themselves not evenly spaced.

*Uniform gentle slopes.*—Where the slope is generally uniform but not steep all light contours should be inked for the guidance of the engraver, especially where marked divergence or discordance exists among them. In general, the light contours should be indicated, at least by short lengths of lines, along every drainage line and every spur crest.

*Cliffs.*—Extreme care must be taken in inking bluffs and cliffs on which not all the contours can be shown. The inked lines should be as sharp and smooth as they can be drafted, so as to reduce to a minimum the chance of their blurring in transfer to the copper. Inasmuch as very closely spaced lines on a drawing tend to run together where reduced in scale and transferred to copper, the inker should aim to leave the engraver's copy as open as possible, and this may be accomplished in part by omitting from the inking any four, three, two, or even single contours wherever two or more are closely spaced on the map. The contours that are omitted in the inking can be interpolated by the engraver, who can work more

rapidly and with more assurance because the copy has thereby been rendered more legible.

Where cliffs are represented by bands of contours and are so numerous as to dominate the topography, as in the Grand Canyon of Arizona, it may be desirable to omit the usual emphasizing of contours and instead to add as many contour numbers as may be needed for identification. Such contour numbers may be most appropriately placed on the contours that otherwise would be heavy.

*Depression contours.*—Contours inclosing depressions or sinks should be distinguished from hill contours either by rows of contour numbers indicating successive depths, instead of successive heights, or by hachures on the downhill side of each contour line. The depressions may be natural, such as occur in limestone regions, or artificial, such as are inclosed by railroad or road embankments. If the depression takes more than one contour, all should be hachured. In intricate areas it is often desirable to indicate the bottom elevation of the basin by figures, or, if space permits, to mark the elevation of some or all of the contours.

Depressions of large extent covering a considerable area on the map are intelligible without the aid of hachures provided they are liberally supplied with contour figures.

*Contour figures.*—Figures of elevation on contours should be inked without shading. On heavy contours they should be placed with a special view to their effectiveness as an aid to the map reader. A sufficient number of them should be used to enable the reader to obtain a contour elevation with but slight examination. It is desirable, therefore, that they be placed in conspicuous positions and that they be distributed with some system. In general, contour figures are most effectively placed on or near the ends of spurs, tops of ridges, or bottoms of valleys and at pronounced changes in slope.

On features taking several tiers of heavy contours the figures may be placed in steplike series. Such series should follow the features on which they are placed in easy, gentle curves. On very steep slopes, where they would be too crowded, the figures should be omitted on alternate heavy contours. Each mountain group or separate map unit should have its own numbering system, so that there may be no need of referring to contour figures across valleys or canyons.

In regions of moderate or low relief the placing of the figures should be governed primarily by the disposition of the larger topographic subdivision. Each of these should have at least one complete set of figures. In areas of exceptionally intricate topography—for instance, in areas pitted with solution sinks or traversed by high cliffs—the figures on the heavy contours may not suffice to make the delineation intelligible, and it is proper to place figures on light contours wherever they will help to remove uncertainty. If need be, figures showing



the elevation of several points may be introduced to supplement the contour figures.

Contour figures should not, as a rule, appear in close proximity to bench-mark and other elevation figures, which, on the other hand, should not be considered as taking the place of the contour figures.

Finally, care should be taken to select a position for contour figures that will accommodate the engraving on the reduced scale of publication.

*Two contour intervals.*—Where two or more contour intervals have been used in a quadrangle (see p. 246) the inker should carefully examine the entire map to ascertain those parts of the quadrangle to which the different intervals apply. Before contour inking is begun full instructions should be sought as to the proposed method of handling the contour inking.

Where it seems desirable to ink additional contours within certain areas, in order to bring out supplemental relief that has been mapped, such additional contours should be inked in dashed lines, in order that they may be distinguished from the contours of the regular system; and a footnote should be added directly under the contour-interval line reading “— foot contours added in dashed lines.”

*Railroad contours.*—The penciled copy should be carefully examined and no excessive or improbable railroad grades, cuts, or fills inked unless the copy is clear and unmistakable. (See “Railroad grades,” p. 250, and “Cuts and fills,” below.)

*Cuts and fills.*—Straight lines representing cuts and fills (see p. 251) should be ruled in, and the inked copy left as sharp and open as circumstances will allow. A slight separation of the lines may be warranted, but where this is not practicable a short stretch of perhaps 0.1 inch or so of one or more lines that are closely spaced may be omitted in the inking and yet leave copy that will be understood by the engraver.

*Use of hachures.*—The inking of hachures should be confined to the representation of depressions (p. 251), mine dumps (p. 234), and such other banks as are not shown by the contours and yet constitute conspicuous topographic features. (See “Use of hachures,” p. 252.)

*Contour disagreeing with elevation.*—An example of permissible topographic license (see p. 253) is the following: A 1,300-foot contour (interval 20 feet) is penciled to represent a sharp summit whose elevation is given as 1,295 feet; both the 1,300-foot contour and the elevation may be inked. To omit the 1,300-foot contour would be to show the summit as flatter than it really is. Where such small differences appear to be fully justified, such topographic license may be taken, but the evidence must be clear that the differences are not the result of error; where error is suspected a question should be raised or the elevation omitted in the inking.



*Alinement of contours.*—The bends of contours in steep drainage channels and on steep ridges should, in general, be in line with one another, and in such places care should be taken in the inking to see that the contours are placed in the proper alinement. (See p. 253.) Careless or hasty penciling may throw contours out of line in steep places, and unless the pencil copy to the contrary is unmistakable, the inker may often be aided in properly alining the contours by lightly penciling a drainage line or a ridge line on which to reconstruct the contour crossings.

*Topographic expression by different authors.*—Where different parts of a quadrangle have been mapped by two or more persons, the contouring of the different authors should be carefully compared before it is inked in order that any minor differences in expression may be reconciled in the inking so far as that may be practicable. Attention should be called, however, to all material differences in topographic expression that are not plausibly explained by such differences as are to be expected where differing types of country are found in the same quadrangle.

#### INKING FEATURES BASED ON AERIAL PHOTOGRAPHS

If an aerial photographic base, such as is described on page 254, has been used in the field, the office inker should, in general, ink only those blue lines that have been penciled in on the final field sheet. A blue line that has not been verified by field penciling should be inked only where there is definite knowledge that the line represents a feature that is intended as a part of the map. Among the blue lines that should not be inked and may or may not have been erased or crossed out by the field engineer are fence lines added for additional control, woodland outlines, and lines of mistaken culture or drainage.

The copy for coastal shore lines and shores of large rivers should not be inked until the status of such shore lines has been determined either by explanations to be found in the field material or by administrative approval in the office. (See last paragraph under "Mapping on aerial photographic base," p. 255.)

#### RECTANGULAR GRID

*Definition.*—A grid is a system of rectilinear lines forming squares of identical dimensions, which may vary according to the requirements. Grid lines may be drawn entirely across the face of the map or may be indicated by marginal registration marks only, as is the Geological Survey practice. Were the registration marks to be connected, in order to form a true grid, the lines would be drawn as straight lines. Each grid line has a numerical designation, and the notation adopted increases eastward and northward only. Distances east are termed

$x$  distances and distances north are termed  $y$  distances. An arbitrary point of origin or zero point is so placed that  $x$  and  $y$  distances are positive.

*Where used.*—Each advance sheet and each published quadrangle map of the topographic atlas and most other topographic maps issued in quadrangle form should carry registration marks for a 5,000-yard rectangular grid, based on the United States zone system described below and in more detail in U. S. Coast and Geodetic Survey Special Publication 59. The registration marks should be plotted outside of and adjacent to the neat line of the map and inked in fine black lines a quarter of an inch long, with the  $x$  and  $y$  figures given for the registration marks nearest the southwest corner.

*United States zone system.*—Inasmuch as it is not practicable to cover the entire area of the United States by a single grid system, based on one central meridian, the country has been divided into zones, designated A to G, each zone covering a range in longitude of 8 degrees plus 1 degree for overlap, or 9 degrees. The middle meridians for the several zones are  $73^{\circ}$ ,  $81^{\circ}$ ,  $89^{\circ}$ , etc., and each of these meridians has an arbitrary  $x$  distance of 1,000,000 yards. The same table can therefore be used for each zone in the system, but the zone within which the map falls must be stated upon the map. An  $x$  distance, when the zone is known, gives then, in effect, a measure of longitude.

*Plotting and checking.*—The plotting and inking of the grid will be done in the section of inspection and editing and must be independently checked by a person other than the one engaged in the computation, plotting, or inking. The names of the plotter and checker of the grid and the names of the computer and checker of the figures representing grid distances on publication scale (see below) should be added to the impression of a rubber stamp provided for the purpose.

*Publication distances.*—On each final drawing representing a map that is to be regularly published by the Geological Survey should be added in ink at the four corners of the projection the  $x$  and  $y$  distances from each quadrangle corner to the nearest grid registration mark, expressed in inches and hundredths of an inch on the scale of publication. The directions in which the inked distances apply should be indicated by arrows, and the figures should be so placed that they can readily be brushed off the advance-sheet negatives.

*Plotting grid on a projection.*—To put a 5,000-yard grid on a quadrangle map which is drawn on the polyconic projection, proceed as follows:

From United States Coast and Geodetic Survey Special Publication 59 take the  $x$  and  $y$  distances for each of the four corners of the quadrangle. These distances are given in yards for all 5' intersections of meridians and parallels in the United States.

To locate grid registration marks for the southwest corner of the quadrangle, subtract the  $x$  distance for that corner from the next higher 5,000 multiple and plot the difference east along the south projection line, then subtract the  $y$  distance from the next higher 5,000 multiple and plot that difference north along the west projection line. To locate registration marks for the northwest corner of the quadrangle subtract the  $x$  distance from the next higher 5,000

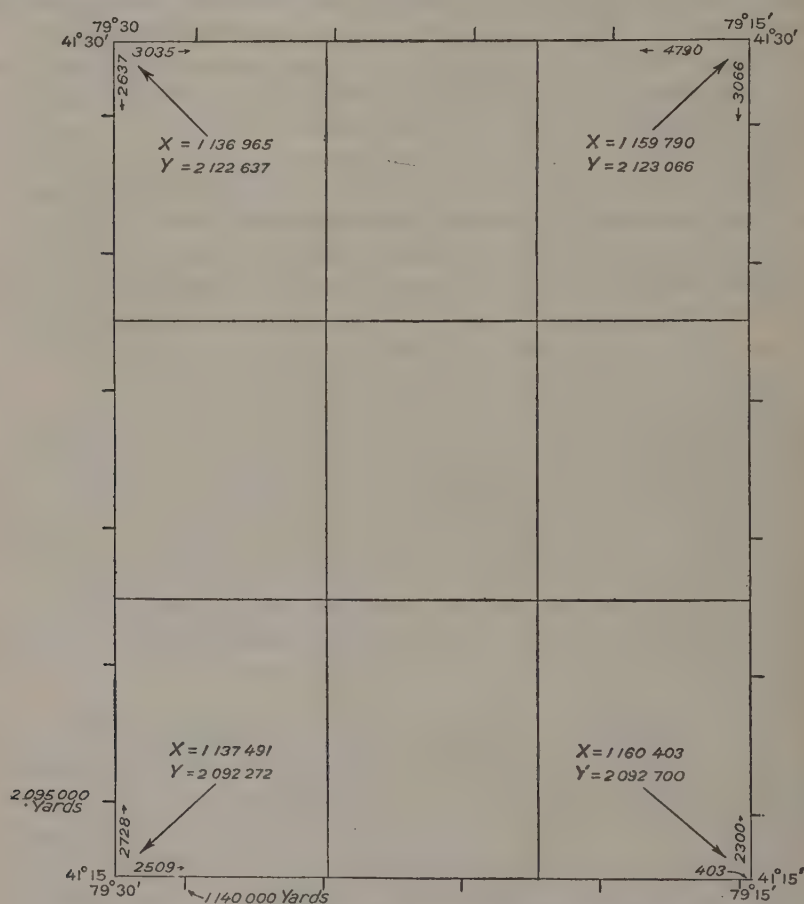


FIGURE 12.—Diagram showing registration marks for rectangular grid

multiple and plot that difference east along the north projection line; then plot south along the west projection line the difference between the  $y$  distance and the next lower 5,000 multiple. To locate registration marks for the southeast corner of the quadrangle subtract the  $y$  distance from the next higher 5,000 multiple and plot that difference north along the east projection line; then plot west along the south projection line the difference between the  $x$  distance

and the next lower 5,000 multiple. To locate registration marks for the northeast corner plot west along the north projection line the difference between the  $x$  distance and the next lower 5,000 multiple; then plot south along the east projection line the difference between the  $y$  distance and the next lower 5,000 multiple.

Intermediate grid intersections can then be interpolated along the four sides of the map. If the projection is very much too large or very much too small a proportionate compensation should be considered in plotting the grid intersections.

Figure 12 gives the  $x$  and  $y$  distances in yards for the four corners of a 15' quadrangle, the distances in yards from each corner to the nearest grid registration mark, the complete  $x$  and  $y$  distances in yards from the point of origin for the grid lines nearest the southwest corner, and the interpolated grid lines.'

### INKING OF CULTURAL REVISION SHEETS

*Field revision sheets.*—The field revision sheets are described under "Field sheets" (p. 179). So much of the new or changed culture, drainage, or relief as has been surveyed in the field should be inked in the three standard colors. (See "Inking of topographic field sheets," pp. 277–298.) Except as indicated below, the inking should be confined to the new or changed features, and the unchanged features will therefore be left in the original faint photolithographic colors. The entire projection should be inked, however, and the sheets should be cut into halves or quarters, as may be most convenient, so that the separate parts when laid edge to edge will make a single continuous map. For this purpose small overhangs may need transfer to other parts before being cut away.

Where the cultural changes are so numerous as to have warranted a complete or nearly complete resurvey of the topography of a small area it will in general be found advisable to ink the entire portion of the sheet representing that area.

*Exception if cultural changes are extensive.*—If the cultural changes are so numerous and widespread that the correction of the black copper plate would cost more than the engraving of a new black plate the entire culture of the quadrangle should be inked. Therefore if cultural changes are extensive, instructions should be sought before the inking is completed.

*Bench marks and other control.*—All existing control stations and bench marks, together with their established elevations, should be inked, whether they represent changes or not.

*"Take out" sheet.*—The purpose of the "take out" sheet is to indicate all roads, trails, railroads, houses, names, and other features which no longer exist and for which the corresponding lines on the copper plates are to be taken out. The field copy of the engraved map



used as a "take out" sheet may, if in good condition, be used as engraver's copy; otherwise the "take outs" should be transferred to a clean copy of the published map. Careful preparation of the "take out" sheet is essential in order that the engraver may have a clear understanding of what is to be taken from the plates before beginning the engraving of the new or changed topography. Where solid areas have been inked on the revision sheets the corresponding areas should be marked for "take out."

*Name sheet.*—In whatever form the name sheet is submitted (see "Names," p. 226), the copy must be complete and clear as to intent. Where a town or other named feature has been moved or changed in appearance the new lettering should be placed in the appropriate changed position.

*Road classification.*—The roads that are to be changed from full double lines to dashed lines and the reverse (see "Road classification," p. 256) should be so inked on the "take out" sheet; and such changes in road classification should be fully explained in the margin.

A separate engraved copy marked "Road classification" will be prepared as copy for the red overprint, in accordance with the instructions given on page 309.

### BORDER CORRECTIONS

Where it is impracticable to join the new work to the maps of quadrangles that have been published on the same scale upon which the new work is to be published, border corrections to the previous maps should be prepared. Such corrections should be submitted on tracing linen, on the scale of field work, and inked in the standard colors used for topographic maps. (See "Map borders," p. 227.)

*Purpose.*—The primary purpose of border corrections is to make maps of adjoining areas match if the maps are published on the same scale. Corrections should therefore be confined to this single object and the correction copy threaded into the previous work within the smallest practicable space and with the fewest possible changes in the older work. Even though the field topographer may inadvertently carry his over-edge mapping farther than may be needed to assure a good joining of the two maps, only so much of such over-edge mapping should be used as correction copy as is absolutely necessary to accomplish this result; any further correction of the older plates would involve needless expenditure.

*Preparation.*—The penciling or inking of correction copy for border corrections should be confined to the exact amount of correction that is needed and should not be extended to include a tracing of any topography that does not itself need correction. As soon as each line of the correction, such as a road, stream, or a contour line,

joins the corresponding line on the other map, the correction should stop, as any further inking for register is not necessary.

A complete correction copy should be prepared for each of the three copper plates involved, but each should be confined to changes that are called for on its respective plate. For example, if the location of a stream is unchanged but the spacing of contours on the stream is changed, the stream should not be inked, as no correction to the blue plate is here needed.

Where the topography is readjusted into a new position, all houses and other cultural features and especially all drainage lines should be added to the inked correction copy so far as a change in their position is involved in the readjustment in topography. Contour numbers should be freely added to all correction copy as an aid in the positive identification of contours in editing, engraving, and proof reading.

*Joining work on different scales.*—Where the previous work is on a smaller scale than that on which the new work is to be published, corrections to the borders of the older map should be made only where the differences indicate considerable errors in the older work, such as a large difference in elevation or an erroneous connection of drainage, that should be corrected on the next reprint of the older map. Minor differences such as may be expected where large-scale work adjoins small-scale work do not require changes in the older plates.

Where the previous work represents surveys that were made many years ago and are probably to be replaced by revised surveys or by new surveys on a larger scale, no correction copy should be prepared.

### QUADRANGLE NAMES

*Provisional names.*—In order to provide for the designation of the names of quadrangles in connection with plans for field work and for cost keeping during the progress of field work, provisional names have been given to all quadrangles in the country. These names are recorded in an administrative-progress book in the office of the chief topographic engineer and are also alphabetically recorded in a typewritten list. Both lists are kept corrected to date as changes are authorized.

As it is not always practicable to select the most appropriate name for a quadrangle in advance of its mapping, or to know whether a name that has been selected represents a city or place that will fall wholly within a quadrangle, many changes in provisional names are made after quadrangles have been mapped.

*Final names.*—As a rule each quadrangle is named after the principal city or place or the most prominent feature within its limits. If the name of the largest place or most prominent feature duplicates a name previously used to designate a quadrangle in an adjoining State or if confusion might result by giving to a new

quadrangle a name that has been used in another State, not adjacent, the name of the second largest place or of some well-known feature is selected.

*Changes in names.*—If it is found advisable to change a provisional name the final name should be selected after the map has been lettered and before the advance-sheet photolithographs are made, when all names and features can be seen in relation to the quadrangle as a whole. Changes in quadrangle names are approved by the chief topographic engineer, and a letter of advice, or copy, is referred to all persons whose records are affected by the change.

## LETTERING OF TOPOGRAPHIC FIELD SHEETS

### SUBMISSION FOR LETTERING

On the completion of the inking of manuscript topographic maps, prepared either for engraving or for photolithography, the final drawing, accompanied by a legible lettering diagram on tracing paper or cloth, should be submitted to the section of inspection and editing for lettering. The lettered sheet should afterward be returned to the person who inked or submitted it, that he may review the complete inking before referring the map for checking.

### LETTERING OF THE MAP FEATURES

*Lettering on oversheet or on original.*—The lettering for the topographic map features is usually done on tracing linen registered over the original drawing of the map, a separate tracing usually being made for each large separate section of the original, as the north and south halves. The advantages derived from lettering a tracing rather than the map itself are as follows: (a) The copper-plate transfer on which the contours are cut is not obscured by the lettering; (b) the names and elevations can be redrafted in their edited positions and thus supply better engraving copy (see p. 334); (c) the advance-sheet names can be printed in a distinctive color from the base; and (d) the lettering can be done and corrected more economically on tracing linen than on the map itself. If the lettering is very light in amount or if the topography is very open, however, the lettering may be placed upon the original.

*Style of lettering.*—The office drawings of field sheets that are to be reproduced in small advance-sheet editions by photolithography and are afterward to be engraved should be lettered by hand in slanting block and italic letters (upper and lower case). The execution of the lettering should be reasonably uniform and based on legibility for the engineer and clear copy for the engraver rather than a wasteful refinement of drafting.

*Punctuation.*—Periods should be omitted on all lettering within the margin of the map.



*Position of lettering.*—The position of the hand lettering should follow the general rules given for engraved lettering on page 329, except that refinements in placing should not be attempted, and allowance should be made for an advance-sheet reproduction in one or two colors instead of the three colors used in printing engraved maps.

*Section numbers.*—On maps to be reproduced on scales of 1:62,500 or larger the section numbers should be included in the lettering. Each section number should, if practicable, be placed in the center of the section or considerable part thereof shown on the map. If the center of a section falls on a road or an area of considerable detail on the map, the section number should be moved slightly away from the center in order that it may be more legible. Section numbers should be inked in slanting block figures.

#### MARGINAL LETTERING

Much of the marginal lettering (pl. 15) is common to all or to many maps and is supplied in the form of pasters, which are printed from type, and such pasters should be used in lieu of hand lettering. In attaching these pasters to the map care should be exercised to avoid rubbing them and thereby decreasing the strength of the lines for reproduction by photolithography.

*Projection figures.*—The latitude and longitude of each projection line drawn across the map should be inked at the margins and usually expressed in degrees and minutes (or seconds) at the four corners and in minutes (or seconds) only on the four sides.

*Federal heading.*—At the upper left-hand corner of the projection should be placed the following heading, with the lower line centered on the upper:

#### DEPARTMENT OF THE INTERIOR U. S. GEOLOGICAL SURVEY

*Quadrangle, State, and county names.*—At the upper right-hand corner of the projection should be placed the name of the State or States within which the area mapped lies, and below this the name of the quadrangle or area. If the entire area falls within a single county the name of that county, in parentheses, should appear below the name of the State and should be omitted from the face of the map.

*Cooperative headings.*—In cooperative surveys the name of the cooperating State, county, or other body, together with the names and titles of the officials representing it, should appear at the middle of the upper margin of the projection. The officials named should be those in office during the period of the survey.

Differing arrangements of headings are necessarily used in different parts of the country, owing to the diversity in State and county organizations. The heading selected should be the shortest consist-



ent with Geological Survey practice and with approval by the cooperating officials.

*Scales.*—At the middle of the lower margin the scale, expressed in the form of a fraction, a bar scale in miles, a bar scale in feet, and a bar scale in kilometers, should appear in the order named. Lithographic prints of appropriate bar scales for the several field mapping scales are kept in stock and should be tested for length after being pasted in position.

*Contour interval.*—Directly under the bar scales should be placed a statement of the contour interval—for example, "Contour interval 20 feet." Where two contour intervals are used both should be stated, and if practicable a statement of the contour on which the interval changes should be added—for example, "Contour intervals 5 and 25 feet, changing on the 400-foot contour."

*Contour interval under water.*—Where under-water (offshore) contours are drawn a statement of the contour interval should be placed directly under the vertical datum line. If additional contours of smaller interval are shown for the lesser depths near shore, such contours should be listed—for example, "Contour interval offshore 20 feet, with the 10 and 30 foot contours added."

*Datum.*—Directly under the statement of contour interval should be placed the statement, "Datum is mean sea level," but if the vertical datum differs from mean sea level, the amount by which it differs should be stated in a note placed in parentheses directly under the datum line—for example, "Readjustment indicates that elevations on this map should be increased by 4 feet." The alternate expression, "Datum is 4 feet below mean sea level," is too ambiguous for public use and should not be used.

*Division engineer.*—At the lower left-hand corner of the projection should appear the name of the division engineer within whose division and under whose general direction the topographic mapping was done. This item is added for advance-sheet and office information only and should not be engraved.

*Topographic authorship.*—Directly under the name of the division engineer should appear a paragraph stating the topographic authorship, with the names arranged in the order of seniority. By authorship is meant the independent survey of an area for which an author is wholly responsible. Traverses that are afterward adjusted into others' work and thereby absorbed will not be considered independent work entitled to credit in this paragraph.

*Author diagram.*—An author diagram should be added at the lower margin showing the respective areas mapped by the men listed as topographic authors. This diagram is intended for advance-sheet and office information only and will not be engraved unless an out-

side organization has been credited with topographic authorship. (See preceding paragraph.)

*Control authorship.*—Beneath the list of topographic authors should appear the name or names of organizations executing either horizontal or vertical control which has been used in the construction of the topographic map—for example, “Control by U. S. Geological Survey and U. S. Coast and Geodetic Survey.”

*Credit for outside data.*—Credit should be given for any outside data used in the construction of the map, whether from Federal, State, or private sources. (See “Data from other surveys,” pp. 178, 344.) Such credit may apply to topography, control, underwater contours, shore lines, or other data.

*Date of survey.*—The date of survey should be given beneath the statement of credit. The date or dates used should represent only Geological Survey topographic mapping and not dates for control or for outside topographic data. Any outside topographic data should have been examined and corrected to the date of the new topography before being incorporated.

*Projection used.*—At the lower right-hand corner of the projection should appear a statement of the projection used, as “Polyconic projection.”

*Horizontal datum.*—Beside the statement of projection should appear the words “North American datum,” if the map is drawn on that datum; otherwise, if the amount of shift in the projection lines necessary to place the map on the North American datum is known, an explanatory note should be added—for example, “To place on North American datum move projection lines 340 feet west and 700 feet south.”

*Joining lines.*—If a map of an adjoining area has been published on a different horizontal datum and joining lines have been inked on the new map, an explanatory note should be added below the statement of horizontal datum—for example, “To join Galatia map use dotted projection corners.”

*Grid and zone.*—Opposite the  $x$  and  $y$  grid lines nearest the southwest corner of the projection the  $x$  and  $y$  distances should be stated in yards. Directly beneath the statement of projection and datum should appear a note stating the size of the grid (if used) and the zone in which it falls—for example, “5,000-yard grid based upon U. S. zone system, F.” (See pp. 298–301.)

*Land lines and topography.*—If the land lines are anywhere omitted because the Land Office plats can not be reconciled to the topography, an explanatory note should be added in the lower right-hand corner—for example, “Note: Land lines pertaining to Tps. 32, 33, 34, and 35 N., R. 4 E., T. 36 N., R. 2 E., and parts of Tps. 34 and 35 N., R. 2 E., are omitted because land plats and topography can not be reconciled

and no corners could be found," or, "Note: As the Land Office plats can not be reconciled to the topography, the land lines are omitted. The few isolated corners found are shown."

*Shore line and height of tide.*—If under-water (offshore) contours are plotted on the map a note should be added in the lower right-hand corner stating the shore line used and the height of the tide—for example, "Shore line is the margin of mean high water 1.8 feet above mean low water at Glymont."

*Names of adjoining quadrangles.*—The names of adjoining quadrangles should be added in parentheses in the middle outer margin on each common border between them. If the scale of the map of the adjoining area is different that scale should be indicated.

*Township and range numbers.*—Township and range numbers in the form "T. 5 S., R. 7 E.," should be lettered on the map margin opposite the center of each township or portion of a township.

*Township diagram.*—A small township diagram, for which pasters are provided, giving the relative positions of sections within a complete township, should be placed on the south border of the original drawing provided there is ample room and it assists in the identification of section numbers on advance sheets. The diagram is not needed on maps where section numbers appear either on the original or on the lettering tracing, and it is not engraved.

*Declination diagram.*—On the lower margin of each map the magnetic declination should be shown by a diagram (see pl. 15) as east or west and stated in degrees. A statement to the nearest half degree will usually be as close as the data warrant. One line of the diagram should be oriented and marked true north, and the other line should be placed in the direction corresponding approximately to magnetic north for the locality represented.

*Filing name.*—On the lower right-hand margin of each map should be placed the name of the quadrangle and State, for convenience in filing.

*Edition and reprint dates.*—In the lower right-hand margin should be indicated the date of publication and the nature of the edition. The first printing of the map should carry the expression, for example, "Edition of 1922"; a reprint, "Edition of 1922, reprinted 1926." If material changes, such as cultural revision or extensive corrections, have been made the map should be regarded as a new edition rather than a reprint, and only the date of the new printing should be stated—for example, "Edition of 1928."

## PREPARATION OF WOODLAND SHEETS

*Submission.*—A woodland tracing should be prepared for each topographic map and should be submitted when the map is turned in for inspection and advance-sheet photolithography. (See "Mapping of



woodland outlines," p. 255.) If the quadrangle contains no woodland of the type defined on page 256, a blank tracing with an inked quadrangle outline should be submitted, across the face of which should be inked the words "No woodland on quadrangle."

*Preparation.*—Woodland sheets should be made on tracing linen, on the scale of the field work, and preferably in two half sheets for each quadrangle. The woodland copy must be made to register correctly over the final drawing of the map. The outer projection of the quadrangle should be fully traced, but only the intersections of all other projection lines appearing on the original. Where an interior projection intersection falls within a wooded area the green shading should be erased at the intersection. The outlines of wooded areas should be inked in firm solid black lines and the woodland areas shaded in by green pencil. The green shading should be carefully done at its outer borders, inasmuch as the copy is reproduced photographically, and any overrun of green will photograph and thereby render the black lines illegible.

*Checking.*—Each woodland sheet should be checked (see "Checking defined," p. 310) and the tracing signed and dated on a stamped form provided for the purpose. The checking should usually be done by the same person who checks the final map. It should consist of an examination of the tracing for completeness of drafting and comparison with the original or other woodland data in the field material. All edges of woodland areas on maps of adjacent quadrangles should be compared for joining.

*Approval.*—Woodland sheets, after checking, should be approved by the division chief, who should indicate his recommendation for printing. The sheets should be finally approved for printing or otherwise by the chief of the section of inspection and editing.

#### PREPARATION OF ROAD-CLASSIFICATION SHEETS

A road-classification tracing should be prepared for each standard topographic map and submitted when the final drawing of the map is turned in for inspection and advance sheet reproduction. It should be made on tracing linen to register over the final drawing, and the classification data should be inked in red. Each tracing should carry at the bottom a key consisting of a red line followed by the words "Hard, imperviously surfaced roads," and a dashed red line followed by the words "Other main traveled roads." The data presented should follow carefully the specifications outlined under "Road classification" (p. 256) and should not be combined with any other required information. The date of the last month on which the data were obtained in the field should also be stated.



## PREPARATION OF LAND-CLASSIFICATION SHEETS

The preparation of land-classification sheets is fully explained under "Mapping of land-classification data" (p. 258). Such sheets should be submitted to the section of inspection and editing for examination when the final maps are submitted for advance-sheet photolithography. After examination and approval by the chief of the section of inspection and editing he will forward the land-classification sheets to the chief topographic engineer for transmission to the chief of the conservation branch.

## CHECKING OF INKED FIELD SHEETS

## CHECKING OF TOPOGRAPHIC MAPS

*Need.*—The need for an immediate checking up of the inked topographic map by a person other than the author or inker arises from the expectation that one who has worked continuously on the map for many days or weeks may, through inadvertence, misinterpret or omit certain essential data or processes or make errors. If two or more persons ink on the same map, a checking is needed in order to reconcile possible differences that may be found between the parts inked by the different persons, owing to varying interpretations of instructions. The checker should therefore not only be a qualified topographic engineer but one who has had no association with the map in hand and who is to that extent disinterested.

*Checking defined.*<sup>4</sup>—The function of the checker is to examine the final drawing of the map and its field material, through all its features and from every point of view that can suggest itself to an experienced topographer, and as a result of this checking to call the attention of the author or inker to such details as appear to have been overlooked, misinterpreted, omitted, or erroneously shown. The checker, however, should be reasonably familiar with the functions of the inspector and of the editor, that he may not waste time in the consideration of purely editorial matters which are to receive due attention later. (See below and also pp. 313 and 320.)

The checking should include the examination of the inked field drawings, lettering tracings, and woodland sheets, also of any corrections that may be necessary to make the new map join maps of adjoining quadrangles that have been previously surveyed.

*Avoidance of duplication.*—Each topographic map in its transmission from the field to the map editor goes through the following hands: (1) Field topographer as author; (2) office inker; (3) checker;

<sup>4</sup> See footnote 3, p. 273.

(4) inspector; (5) control examiner; (6) map editor. Nos. 1 and 2 may or may not be the same person; the others are different persons. Checking and the inspection and editing of topographic maps are based upon a procedure that allows only so much duplication of work as may be necessary to insure that no errors or omissions have been made; and to this end the duties involved in the several stages listed in this paragraph are set forth in some detail in the pages that follow.

*Attention to checker's questions.*—Questions should be referred by the checker to the person in immediate charge of the office inking of the sheet; such questions as apply to parts of the sheet that have been mapped or inked by others who are then in the office should be referred to them for attention, unless in the judgment of the topographer or inker in immediate office charge of the sheet such further reference is deemed unnecessary, in which case he himself may reply to all questions raised by the checker.

Checker's questions that can not be answered by anyone in the office, for the reason that an absent author or inker alone has the needed information, should so far as practicable be referred by letter to the author or inker. Such references may be made before advance-sheet lithography if the advance sheet is not thereby delayed, but inquiries are best handled by indicating the questions on an advance sheet of the map, that the absent author or inker may the better visualize the subject-matter. If all authors and inkers of a map are absent from the office the checker should himself make all possible corrections and refer by letter to an author or inker only those questions about which there is reasonable doubt as to procedure or lack of information.

*Use of tracing paper.*—In general, the checker's notes and queries should be placed on tracing paper registered over the inked map; questions should not be indicated by drawing pencil lines across the face of the map, for black pencil lines are strongly photographic, and erasures will weaken other inked lines. The checker's oversheets should be destroyed after they have served their purpose, outstanding questions of importance, if any, having been transferred in some appropriate way, such as writing them on the margin of the original, where they remain for future action.

#### SCOPE OF CHECKING

In general, the scope of checking is covered by the printed form reproduced on page 312, and this form should serve as a guide; it should, however, be regarded as suggestive rather than complete.

RECORD OF CHECKING.....QUADRANGLE

TOPOGRAPHER	CHECKER	SUBJECT OF EXAMINATION
		<ol style="list-style-type: none"> <li>1. MARGINAL LETTERING, coordinate figures, township and range figures, scale, declination, statements of authorship, projection and datum, author and inking diagrams, cooperative headings.</li> <li>2. NAMES, of post offices, cities, towns and villages, civil divisions, railroads and railroad stations, streams, highways, mountains.</li> <li>3. FIELD NAME SHEET, compare with lettered sheet.</li> <li>4. PUBLIC-LAND LINES, found corners, section numbers, location or mineral monuments.</li> <li>5. CIVIL BOUNDARIES, national, State, county, county subdivisions, city, park, cemetery. Boundary monuments.</li> <li>6. RESERVATION names and boundaries, national forests, monuments and parks, Indian, land grants.</li> <li>7. ROADS, houses, schoolhouses, churches; trails. Check final drawing against other field sheets.</li> <li>8. RAILROADS, trolley lines, switches, power lines, pipe lines.</li> <li>9. BRIDGES, ferries, fords, dams, tunnels.</li> <li>10. CONTROL symbols, level, triangulation, traverse.</li> <li>11. MINES, mine dumps, quarries, prospects, oil and gas wells.</li> <li>12. STREAMS, double or single line, intermittent, canals and ditches.</li> <li>13. LAKES, ponds, reservoirs, springs, wells.</li> <li>14. MARSH in general.</li> <li>15. CONTOURS, cliffs and cuts and fills, depressions, under-water contours.</li> <li>16. FIGURES of elevation, contour figures.</li> <li>17. BORDERS and names of adjoining maps.</li> <li>18. OVERSHEETS, woodland, road classification, land classification.</li> </ol>

Place check marks in columns above opposite each subject and date and sign below.

\_\_\_\_\_, 19\_\_\_\_

(Topographer)

\_\_\_\_\_, 19\_\_\_\_

(Checker)

### SUGGESTIONS FOR CHECKING

*Material.*—The field material turned over to the checker by the topographer in charge of the sheet should agree with that listed on the sheet jacket filed in the section of inspection and editing and there listed under the heading "Received from the field." Supplemental checking material may include State, post route, and Land Office maps, postal and railway guides, and other authorities if appropriate.

*Traverse sheets.*—Data found on traverse sheets should be checked with the final map from a broad rather than from a literal point of view, for the reason that the topographer may have had occasion to improve the shape of a road or contour, replot a house, or erase some traverse feature that has not been considered appropriate for the map.

*Control.*—The checker should obtain lists of the control data used on the quadrangle, preferably those used by the field topographer, and compare the map with them. He should not seek the latest adjusted values of level bench marks, as that will be done during the control examination in the section of inspection and editing. Here the chief checking function is to see that all control is on the original prior to advance-sheet photolithography. The office names of triangulation points and the office numbers of transit-traverse stations should not be called for by the checker; they are added to the inked map after the control examination above referred to.

*Streams.*—The checker may properly call attention to apparent discrepancies in the amount of classification of drainage inked on a map, but resulting changes in the original drawing should be made only after full consideration by the author-topographer or inker. The proper coordination of drainage as shown on topographic maps is complex at best and is among the matters considered in the inspection examination of the sheet.

*Elevations and contours.*—All elevation figures should be compared with the contours; and all contour numbers should be compared with the elevations and with one another. Doubtful points of application of figures of elevation should be questioned. The checker should ask for the inking of more figures of elevation if those inked are not adequately distributed.

*Names and lettering.*—The lettering tracing should be compared with the field name sheet; and post office, railroad, and station names should be verified. All names should be examined. Names should be requested for prominent unnamed features, especially schools, isolated localities, streams, and conspicuous mountains and lakes.

*Woodland sheets.*—Woodland tracings should be examined by placing them over the map and by looking for register and for completeness of outlines and green shading, also for accuracy of tracing if the woodland outlines are shown upon the original. The woodland borders at the edges of the tracing should be compared with any woodland sheets for adjacent quadrangles. Woodland tracings of published maps are permanently filed in the section of inspection and editing.

*Signature.*—When the checker is satisfied that his notations have received proper attention he should affix his inked signature, with date, on the original drawing and on the woodland sheet within a stamped form provided for the purpose.

#### CHECKING OF CULTURAL REVISION MAPS

Inasmuch as no advance sheets are made to represent the results of cultural revision surveys, the cultural revision sheets are not checked. To avoid unnecessary duplication the sheets are so carefully scrutinized in the editorial and control examination that no prior checking by a topographer will in general be needed other than that by the author or inker.

#### INSPECTION OF TOPOGRAPHIC MAPS

##### SUBMISSION

On the completion of the checking of the topographic map and its return to the topographer who inked it, the topographer should submit the map and the lettering, woodland, land-classification, and



road-classification tracings and adjoining border corrections, together with all field-map material, to the chief of the section of inspection and editing for inspection, advance-sheet photolithography, control examination, editing, and further transmission for engraving or otherwise as may be appropriate.

#### INSPECTION DEFINED

The term "inspection" as applied to an inked topographic map means an examination that is made immediately after the checking of the map and before the map is approved for advance-sheet reproduction. The inspection examination should assume that the checking has been adequately done; if the appearance of the map suggests otherwise the inspector may return the map for additional checking. The inspection of the map should also be made with the functions of the map editor well in mind, in order that there may be no unnecessary duplication of examination. The time spent in the inspection of a map will differ with different maps, but a day should suffice for the average map; additional time will be required for maps that are found to need a closer inspection.

The inspection of topographic maps should be made primarily from the point of view of the field topographic engineer and thus should be assigned to one who has had such experience. The inspection should also be made from the point of view of one who has had an adequate office experience. These two qualifications, when combined with an experience that is acquired only through the examination of many maps representing all sections of the country, may reasonably be expected to result in an inspection that will quickly appraise an inked map as to its completeness and general coordination with other maps and as to its conformity with Geological Survey policies and standard practices.

#### NEED OF INSPECTION

Experienced topographic engineers working in a country to which they are accustomed will produce a map of known standards and one that will be expressed from known points of view, and such a map will need a minimum of inspection; likewise a checker of experience, when examining a map of an area located in a general section of country in which he has had personal training, will read the map with recognized efficiency. But the personnel of a large organization is perforce made up of men who have had varying lengths of service and corresponding experience, and as the numerous maps made by the topographic engineers of the Geological Survey represent the great variety in types of topography that is to be found over the country at large, differences in the interpretation of standard instructions are to be expected. It is a province of the inspector

to examine all maps in a comparative sense and to call the attention of the proper division engineer to such modes of treatment as seem to depart from the desired standards, differences in terrain duly considered. In requesting or suggesting major changes that appear desirable, the inspector should act through the division chief or his delegate; minor changes may be taken up directly with the topographic author or inker involved. There should be the fullest cooperation between the inspector and the engineer in charge of the division in which the area represented on the map under inspection falls.

The inspector's field of service does not, however, lie alone in the examination of completed maps; he should advise those engaged in the office preparation of the drafted copy at all appropriate times and in so far as opportunity permits. As the individual engineers are encouraged to consult freely with the members of the section of inspection and editing on matters pertaining to the office drafting of topographic maps, the inspector is expected to offer the fullest cooperation, to the end that many matters may be cleared up before the map reaches the inspection stage.

#### ATTENTION TO INSPECTOR'S QUESTIONS

In general the questions raised by the inspector should be referred to the division or section chief having administrative charge of the map under inspection; but minor questions should be referred to the topographer or inker in direct charge of the office work on the map.

The inspector should bear in mind that the author or inker of a map is the one most directly concerned when additions or changes are found to be desirable or necessary and that he should be fully advised when one of his maps needs further attention, that he may correct it and note the changes for future use. The inspector therefore should not himself make corrections to maps, except in cooperation with the author or in the author's absence from the office.

#### SCOPE OF MAP INSPECTION

In general, the scope of an inspection examination of a topographic map is covered in the preceding paragraphs, but certain features that in practice demand especial attention may be briefly set forth.

*Appraisal of checking.*—The first duty of an inspector should be to appraise the previous examination by the assigned checker in order to be assured that the checker has covered the ground expected of him. To determine this point the inspector may make inquiry when appropriate and may ask for further checking if that is needed.

*Drafting.*—The map should be examined with reference to the strength of the inked lines as good copy for reproduction by photolithography; and if the inking shows congested places where a clear photolithograph could not be reasonably expected such steps should be taken as seem warranted.

*Completeness of copy.*—The entire map should be rapidly inspected for completeness of copy, both within the margin and in the marginal lettering. All marginal notes, scales, names of adjoining quadrangles, etc., should be read for consistency and correct application to the map in hand.

*Drainage.*—The classification of drainage and the amount of drainage that is inked will differ with different topographers or inkers, and as no complete rules can be written, these features as expressed on topographic maps will need further consideration by the inspector, who may request slight changes to reconcile the treatment with existing standards. To this end the drainage as shown on maps of surrounding areas should also be examined, and adjustment of such differences as may be found should be made so far as practicable from the data on hand.

*Detail.*—As topographic expression is more quickly and more accurately read on an inked map than on the penciled field sheet, the inspection should include a comparison of the work of the different men who have contributed to the field authorship or office inking, and this comparison should be extended to the maps of surrounding areas that have been surveyed. Attention should then be called to such contrasts in expression or treatment as may have escaped previous notice but appear not fully justified by known types or standards.

*Bench marks and useful elevations.*—Although the final examination of the control will be made later, after the advance sheets have been issued, the inspector should see that the "B M" letters and crosses and their elevation have been inked and that there has been a reasonable interpretation of the instructions for the inking of useful elevations.

*Standard symbols.*—The drawing should be looked over for the possible misuse of a symbol to represent a topographic feature or the use of a standard symbol that has not been approved for Geological Survey maps.

*Signature.*—When the inspector finds that the map is in complete form for photolithography and is assured that any comment has received due attention, either by way of changes in the map or by notation for further inquiry and attention, he should attach his inked and dated signature within the form that is stamped on each map for that purpose.

## APPROVAL OF TOPOGRAPHIC MAP DRAWINGS

*Approval by division engineer.*—On the completion of the final drawing of the topographic map the drawing should be approved by the division engineer in charge of the division in which the area mapped falls. The approval should be entered in ink and dated within the stamped form provided for the purpose. Such signatures will be regarded as authority for advance-sheet photolithography and also as approval for engraving, provided the map is carried on the current engraving docket approved by the chief topographic engineer and the director. The drawing as approved by the division engineer is understood to be subject to editorial review before engraving and therefore subject to such editorial amendment as may, in the judgment of the chief of the section of inspection and editing, be found desirable.

*Approval by chief of section of inspection and editing.*—The original drawings of topographic maps should be finally approved by the chief of the section of inspection and editing. Such approval will be understood as indicating that the previous examinations have been adequately made, that the needs of the map and questions of expediency have been adequately considered, and that there is a full understanding with the division engineer concerned or with the chief topographic engineer as to the further handling of the map for such reproduction as has been or will be duly authorized.

*Changes in map after approval.*—No changes in the original drawing of a topographic map can be made after the final approval of the drawing unless they are called for as a result of the editing or unless they have been approved by the chief of the section of inspection and editing and recorded. This rule is necessary because the editing of the map is partly done on an advance-sheet reproduction of the drawing made immediately after its approval, and any unrecorded changes in the original drawing will result in unrecorded differences between the advance sheet and the original and may cause confusion in the engraving.

*Approval of woodland tracings.*—The woodland tracing should be checked and signed by the topographer assigned to check the map; it should be approved by the division engineer concerned; and it should be finally approved for printing or otherwise by the chief of the section of inspection and editing.

## ADVANCE SHEETS

*Transmission of maps for photolithography.*—After approval, the final drawing of a topographic map should be transmitted by the chief of the section of inspection and editing to the chief engraver for advance-sheet photolithography. Before the advance-sheet edition is printed a proof is submitted to the section of inspection and editing and is read, corrected, and returned approved.



*Purpose of advance sheets.*—The purpose of the advance-sheet edition is to afford an immediate reproduction of the completed topographic map for the temporary use of cooperating State officials, Government bureaus, engineers, geologists, and others and for Geological Survey office use, pending the publication of the engraved map. Advance sheets are marked "Advance sheet subject to correction," and comment is invited from anyone qualified to submit constructive criticism. Most advance sheets are issued with the topographic base printed in a dark chocolate-brown color and the lettering overprinted in black, in order that the names may be easily readable and also in order that the base may be transferred to the copper plates without a transfer of the names until they are needed.

*Long side bar scale.*—A long bar scale of miles should be transferred to each printing plate before the advance sheets are printed, and for this purpose the engraving division will keep zinc plates on hand prepared from drawings made by the topographic branch.

*Advance sheets to authors and others for comment.*—An advance sheet will be sent to each author named on the map, to the cooperating official directly interested, to the Forest Service if a national forest is shown on the map, and to any other appropriate person or office from whom thoughtful criticism is likely to be received. Each advance sheet sent out for criticism will be stamped: "This proof is for criticism. No later proof will be sent. Submit corrections promptly to chief topographic engineer, U. S. Geological Survey, Washington, D. C." Geological Survey authors receiving such an advance sheet are expected to examine the representation of the areas credited to them and to return the sheet promptly with their comment. Such corrections or suggestions as are made should be applied to the original drawing of the map in so far as they can be approved and expressed in correct form. The copies returned by the authors should then be filed in the sheet jacket for the editors' information when the map is prepared for engraving.

Comments and corrections for first editions of topographic maps are invited only on advance sheets of the maps, and no further proofs are sent out for criticism. (See "Plate changes after editing," p. 322.)

*Size of advance edition and reprints.*—Inasmuch as the advance sheets are distributed free and to professional map users only, the editions printed are small and should be restricted to the estimated number that may be needed to supply the mailing list and office files. The plates from which the advance sheets are printed are held until the map is engraved and are then cleaned off for further use; but in the meantime the advance sheets may be reprinted if the demand for additional copies justifies a reprint.

*Mailing list for advance sheets.*—A mailing list for advance sheets is maintained in the section of inspection and editing. Names are placed on this list only after proper administrative approval.

## TRANSMISSION OF WOODLAND, LAND-CLASSIFICATION, AND ROAD-CLASSIFICATION TRACINGS

*Woodland.*—Woodland tracings, after approval, should be permanently filed in the section of inspection and editing. Woodland copy that has been approved for printing should be forwarded to the engraving division for reproduction when the map to which it applies reaches the stage of first plate proofs. When the woodland color has been printed the woodland tracing will be returned for filing.

*Land classification.*—Land-classification tracings or sheets and written reports that have been prepared in conformity with instructions on pages 258–261 should be submitted to the section of inspection and editing for examination and approval. Each land-classification tracing, attached to a copy of the topographic map it represents, will be transmitted by the chief topographic engineer to the chief of the conservation branch.

*Road classification.*—The road-classification tracing or sheet should be submitted to the section of inspection and editing at the time the original maps and field material are submitted. The road-classification data will be filed for later consideration when the copy for the red overprint showing road classification is prepared, just prior to the printing of the map.

### CONTROL EXAMINATION

The final drawings of all topographic maps should be examined in the section of inspection and editing for the completeness and accuracy of their control, both horizontal and vertical. This examination should in general be made after the advance sheets have been issued if the maps are to be engraved; if the maps are to be photolithographed only, the examination should of course be made before photolithography.

*Need.*—Inasmuch as the proper plotting of the initial control for a proposed map is a fundamental preliminary to any topographic survey, its correct expression on the published map is of prime importance. Although the nature of the control examination is editorial, the task calls for a previous field experience. As the control for a map may have been run in part during the progress of the topographic mapping, as the control data that are supplied to the topographic engineers may be divided between several men working on the same or adjoining quadrangles, and as party personnels may change, experience has shown that a check-up for completeness is necessary. For example, one inker may inadvertently fail to ink control used by another; occasionally only preliminary field determinations were available for the elevation of bench marks but can now be replaced by adjusted figures; control that was of value in

field mapping and that has been inked on the map may not be appropriate for engraving and publication; or control that has been reported destroyed may be inadvertently inked.

*Scope.*—The control examination should consist of a thorough search in the records of the section of computing for all control data affecting the area under examination and the comparison of these data against the control as shown upon the original drawing submitted. So much of the control as is found appropriate for engraving and final publication should be left in black on the original, and such as is not to be published should be changed to red and not engraved.

The figures of elevation of supplementary bench marks that do not represent good engineering benches should be changed from black to red, and these bench marks will not be engraved.

Copy should be prepared for the appropriate credit for such outside control as may have been directly used in the topographic mapping. In general, control that has not been used in the topographic mapping should not be published on Geological Survey maps.

The declination diagram should be checked by comparison with the records of the section of computing and by the isogonic chart issued by the Coast and Geodetic Survey.

*Triangulation and traverse designations.*—The names of triangulation points should be lettered in hair-line black on the original opposite the triangle, unless the feature on which the point falls is itself sufficiently named on the map to serve as an identification of the triangulation point. Names thus shown in hair line will not be engraved. Transit-traverse stations should be further identified by hair-line black lettering giving the recorded number of the station—for example, "T Tr 17."

## EDITING OF TOPOGRAPHIC MAPS

### CHARACTER OF EDITING

*Editing for engraving.*—Topographic maps that are to be engraved should be edited before transmission for engraving. The engraver's copy should consist of an inked original or final drawing and lettering tracings, together with supplemental instructions written in red ink on an advance sheet or other photographic copy of the map.

The editorial examination should consist of a careful scrutiny and, if necessary, rearrangement of the original drawing and lettering tracings to insure general conformity with Geological Survey instructions and practice. Changes in the topographic base should not be made by the editor, but if such changes appear necessary he should question them on the editing work sheet (see p. 322), and the action then taken by the topographic engineer or inker in charge of the map



or by his representative should be written alongside the written marginal question, where it should remain as a record for the editing files. It is a function of the editor to arrange for the proper placing and spelling of all names, marginal notes, and numerals according to existing practice or instructions but to question them only when a fact is uncertain.

*Engraving docket.*—An engraving docket should be prepared in the section of inspection and editing early in each calendar year. This docket should list all new topographic maps authorized for engraving in the order in which they are to be taken up. The priority interests of the several States in which the mapped areas lie are first indicated by the topographic division engineers, and a resulting draft of the proposed docket should be submitted to the chief topographic engineer and to the chiefs of the other Geological Survey branches concerned. The final engraving docket is then approved by the director. Additional or special engraving out of the docket order can be authorized only on approval by the director.

*Editing docket.*—A topographic map will not be taken up for editing unless it has been listed on an engraving docket or unless its engraving has been provided for by a separate letter and authorized by the director. The editing of topographic maps should be taken up in the order in which the maps are placed on the engraving docket, but only in so far as they have been put on an editing docket. To be available for editing the map must have been examined for control; the advance sheets must have been issued, if to be printed; and all outstanding questions of major importance must have been settled. The sheet jacket should then be indorsed "On editing docket," dated, and initialed by the chief of the section of inspection and editing; and the map in the jacket, together with the appropriate oversheets and other field material needed in the editing, forwarded to the editing rooms.

*Editing questions.*—Questions raised in the editing should be referred with the map in the jacket to the topographic engineers or inkers engaged in the office preparation of the copy or in their absence to some designated representative, that they may answer queries, supply omissions, explain discrepancies or apparent errors, review the corrections and rearrangements made by the editor, and clear up questions of interpretation or of legibility of essential data that should be clear copy for the engraver. Editing questions should be written in pencil on the margin of the editing work sheet, within a green penciled reference mark, and replies should be written in pencil and should indicate clearly the action taken—for example, "Yes; original changed."

Outstanding questions that are not answerable from office data should be placed on an advance-sheet copy of the map and sent to



such author topographers as may be in the field or to other persons who may be considered competent to answer them, and they should receive prompt attention. Other outstanding queries should remain on the margin of the editing work sheet for further adjustment.

*Plate changes after editing.*—Edited topographic maps approved for engraving constitute final copy for engraving, and the very minimum of changes will be made after the maps have been engraved on copper. Topographic engineers and administrative officials must therefore make in ample time all corrections that they wish incorporated in the final publication, and no corrections to plate or combined proofs should be made except under extraordinary circumstances where the corrections are imperative. No combined proofs should be sent to field men or to officials of other organizations for comment. Such corrections as they wish to make for subsequent editions can be filed on a published copy of the map.

#### SCOPE OF EDITING

The details of the topographic map editing that appear under the headings given below should not be regarded as complete but only as covering a large part of the scope of editing. Map editors are expected to find them suggestive of other details which in many individual maps will also need consideration and attention.

Editing work sheet.	Comparison with other maps.
Scale and contour interval.	Waterlining and tints.
Marginal lettering and scales.	Detailed examination of original.
Adjoining borders.	Depression contours.
Post offices.	Punctuation.
Railroads and stations.	Position of lettering.
Locality names.	Abbreviations.
State boundaries.	Selection of elevations for engraving.
County boundaries and names.	Position of bench-mark letters and figures.
County subdivisions.	Position of elevation figures.
Incorporated places.	Position of contour figures.
United States Geographic Board.	Style of engraved lettering within the map.
Land lines.	Style of engraved marginal lettering.
National forests.	Style of figures.
National parks.	Parts of quadrangles.
National monuments.	Edited map to topographer.
Indian reservations.	Letters of inquiry.
Private land grants.	New lettering tracings.
Federal game and bird preserves.	Instruction sheet for engraver.
State parks and reservations.	Filing of editing notes.
Military reservations.	
Power transmission lines.	

*Editing work sheet.*—The editing work sheet consists of an advance-sheet photolithograph (see p. 317) or a photographic copy of the original map or final drawing of the map that is to be engraved. If the engraving copy consists of several large-scale maps, as when four  $7\frac{1}{2}'$

maps are to be reduced and combined into one 15' map, the editing work sheet should be a single dummy made up from the separates photographed to the scale of publication.

On the editing work sheet the editor should enter in black pencil all notes and queries relating to discrepancies or apparent errors found in the course of the editing but should indicate in red ink instructions to the engraver. Such notes, queries, and instructions should for the most part be written on the margin of the paper and connected by a line with the feature to which they relate. All boundary lines to be published should be legibly emphasized by colored pencil lines drawn on the work sheet along them, a separate color being used for each kind of boundary; and a key should be added in the south-east margin explaining the color distinctions thus used. Certain data and names that are not to be engraved are inked on the original in red (see "Colors," p. 279); other data or names that may be eliminated in the editing should be indicated on the work sheet by red lines drawn through them. The original drawing should not be changed save where changes in the marginal lettering are necessary. (See "Marginal lettering and scales," below.)

*Scale and contour interval.*—The scale and contour interval for the engraved map must be clearly indicated. If the editing is done upon a sheet that has been photographed to a scale larger than that of publication, due allowance should be made for the reduced size of the engraved map in providing for lettering, numbers, etc., in close places.

If the contour interval for the engraved map differs from that on the engraver's copy, complete and adequate copy must be furnished to the engraver for both heavy and light contours on the new interval.

*Marginal lettering and scales.*—All marginal lettering should be examined for its correctness and completeness of statement as applying to the map in hand, for any changes in wording that may be needed in order to comply with existing standards, and lastly for its best placing on the plates. The engraver should be instructed as to what names of adjoining quadrangles are to be engraved, the kind of bar scales to be used, and the datum upon which the map is drawn if other than North American datum. The author diagram should not be engraved unless an outside organization has been credited with topographic authorship. Where changes in marginal lettering are indicated in red on the instruction sheet for the engraver the corresponding changes should be made on the original and in the usual inked or pasted form, in order that there may be no misinterpretation of engraving copy. Erasures of features such as military number and diagram, advance-sheet label, and field bar scale and other routine changes that are well understood by the engraver and apply to all sheets need not be made on the original.

*Adjoining borders.*—The edges of the maps of adjacent quadrangles on the same scale should be compared to see that for each line, contour, road, or boundary drawn to the exterior projection line on one map there is a corresponding line on the other, and that these lines meet. Edges should be compared in a general way with maps of adjoining quadrangles on different scales to detect discrepancies that are not explained by differences in scale. Names of features that are common to two or more maps should be compared. The new map should be made to join and agree with the one already engraved so far as possible, but if this can not be done a correction of the older map should be called for. (See p. 227.) The margins of the instruction sheet sent to the engraver should then be marked "Join to ———," "Join to ———; see corrections herewith," or "Cut to projection," as appropriate.

*Post offices.*—Post offices should be compared with the post-route map for general location, with the Postal Guide for spelling, and with the monthly supplement to the Postal Guide for latest information as to the establishment or discontinuance of offices. The names of post offices discontinued through rural delivery should be retained as locality names if appropriate.

*Railroads and stations.*—Names of railroads and railroad stations should be compared with the Official Railway Guide. "Bullinger's Shippers' Guide" should be used to identify places having different names for the post office and the railroad station; and "Poor's Manual of Railroads" to trace out railroads that are no longer listed in the Official Railway Guide. Local railroad folders should be obtained if necessary. (See p. 232.)

The abbreviation "R R" should not be used, and the word "railroad" should be used only where it is a necessary part of a descriptive title or name—for example, "Lumber Railroad" and "Central Railroad of Oregon." The term "division," signifying merely an operating unit, should not be used, but "branch" or "line" as appropriate may be used to identify the different lines of a road appearing on the same or adjoining maps.

In the selection of railroad names where large systems or lines are involved, judgment will be required, and inquiry will often be necessary to determine ownership, control, operation, or trackage rights. Where a road has lost much of its former identity as a separate road through absorption or lease by a larger and operating organization, the name of the larger organization should be used, but without the word "system" or "lines"—for example, the road formerly known as the "Northern Central" is now better identified by the system name "Pennsylvania." Where, however, the affiliation does not include operation, the name of the operating road should be used—for example, "Baltimore, Chesapeake and Atlantic" should be retained,



although this road is affiliated with the Pennsylvania system. Where a road is operated not only by its own well-known organization but also as a part of a larger system that exercises part control, as in the running of through trains, both local and system names should be used—for example, "Southern Pacific System (Galveston, Harrisburg and San Antonio)." Preference is to be given to the name of the railroad that owns a line rather than to that of one that has trackage rights only. For a line under joint ownership the name of the road operating the line should be used.

*Locality names.*—In addition to towns and localities designated by their post-office or railroad-station names, all other well-known localities should be designated by local names established through recognized usage. Among such localities are country schools, cross-roads, and isolated churches. If the name of a feature, as a bridge, is also a locality name, preference should be given to the locality designation by the use of roman type. If the name of a railroad station differs from the name of a corresponding post office, or if either differs from a more widely used local name, the name by which the place is better known should be used, followed underneath by the other name, with "P O" or "Sta" affixed as the case may be.

*State boundaries.*—Bulletin 689 should be consulted as to State boundaries, and any doubtful application of the statutes should be fully investigated. (See field instructions, p. 236.)

Although the province of the topographic engineer is first to identify the boundary line on the ground and then plot it on his map, the ground conditions are sometimes found to be uncertain in that lines may be indefinite or not marked, and if they lie in streams with shifting channels or banks they are difficult to determine; and the line may not have been accepted by those living on both sides of it or by the proper county or State authorities and may be in dispute or even in court. The location of a State boundary line should therefore be subject to careful review in the editing.

The following principles should be kept in mind: (a) A line marked on the ground and once accepted by competent authority is the real boundary regardless of a statute to the apparent contrary. (b) The description of a particular bank or point in a stream may be indefinite in wording or difficult of application, and past practices or rulings should be sought. (c) Early Supreme Court decisions that a boundary moves with a gradually shifting channel or bank but does not follow sudden shifts or cut-offs have in general been followed in recent decisions. (d) If the statute defines a boundary line as that of some channel or other part of a river, the location of the river itself at the time the statute became effective should govern, unless there has been a gradual change in the position of the river, as just indicated. The generally accepted location of the rivers that form



State boundaries at or near the time of the enactment of most of the statutes defining the boundaries may be found on the plats of the General Land Office that were prepared at about such times. Supreme Court rulings must govern if they have been made, but few decisions that affect the details needed on Geological Survey maps have been handed down by the court, and it may also be necessary to differentiate between gradual and sudden changes in a river course.

*County boundaries and names.*—County boundaries and names should be compared with post-route maps, and information as to newly created counties should be sought in the monthly supplement to the Postal Guide. Any further necessary data should be sought through letters of inquiry or by an examination of the State statutes, which are obtainable from the Library of Congress. (See p. 236.)

*County subdivisions.*—The subdivisions of the county should be first verified, as to kind, by the authorized list of county subdivisions legal for each State (see p. 237), and then by the Census reports in which all such subdivisions are listed. As the subdivisions of the county in some States are omitted on Geological Survey topographic maps, the policy that has been adopted should be ascertained in each case of doubtful application.

*Incorporated places.*—For incorporated places the list given in the Census reports on population should be consulted, and any absence of boundary lines should be questioned.

*United States Geographic Board.*—The decisions of the United States Geographic Board must be used for the names and spellings of the features listed and described in its reports and bulletins. If, however, the present local usage appears to differ persistently from a board decision, a review by the board should be requested. If other recognized authorities differ with Geological Survey topographers as to names or spellings of features upon which the board has not yet acted, a decision by the board should be requested.

A card list of the decisions of the United States Geographic Board, arranged by States and counties, should be maintained in the section of inspection and editing. The list should be kept current and should be referred to when each new map is edited. Decisions applying to maps already printed should be placed in the correction files when the decisions are received from the board.

The following are some of the principles adopted by the United States Geographic Board:

(a) Names suggested by peculiarities of the topographic features designated, such as their form, vegetation, or animal life, are generally acceptable, but duplication of names, especially within one State, should be avoided. The names "Elk," "Beaver," "Cottonwood," and "Bald" are altogether too numerous.

(b) Names of living persons should be applied very rarely, and only those of great eminence should be thus honored. No personal names should be attached because of relationship, friendship, or personal interest.

(c) Long and clumsily constructed names and names composed of two or more words should be avoided.

(d) The possessive form of names should be avoided unless the object is owned by the person whose name it bears.

(e) The multiplication of names for different parts of the same feature, such as a river or mountain range, should be avoided. Only one name should be applied to a stream or mountain range throughout its length.

Such names as "East Fork" and "North Prong" for branches of a river should be avoided unless there is a special reason for their adoption. Independent names should be commonly selected.

*Land lines.*—Land lines and township and range numbers should be verified by comparison with the State maps of the General Land Office; in case of apparent disagreement the township plats may be examined for confirmation, but discrepancies should be questioned. Section numbers should be omitted on scales of 1:125,000 and on smaller scales.

*National forests.*—The boundaries and names of national forests should be verified by the latest maps and lists issued by the Forest Service and by Presidential proclamations and Executive orders, and further verified if necessary through inquiry at the office of the Forest Service.

*National parks.*—The latest annual report of the National Park Service should be consulted for lists of national parks administered by the Department of the Interior and by the War Department. Boundaries of national parks should be verified by the descriptions given in the acts creating them, by any existing maps, and, when necessary, through inquiry at the offices of the National Park Service or the Chief of Engineers. The existence of national parks should be further verified by the General Land Office State maps.

*National monuments.*—The latest annual report of the National Park Service and the check list issued by the Forest Service should be consulted for lists of national monuments administered by the Departments of the Interior, Agriculture, and War. Boundaries of national monuments should be verified by proclamations describing them, by subsequent Executive orders, and by inquiry if necessary.

*Indian reservations.*—Indian reservations should be verified by the State maps of the General Land Office and as to their boundaries by existing maps, by the descriptions given in the acts creating them, by reference to the township plats of the General Land Office, or through inquiry at the Office of Indian Affairs.

*Private land grants.*—Private land grants and donation tracts should be checked first by the General Land Office State maps and then by the township plats.

*Federal game and bird preserves.*—The United States Biological Survey check list of Federal game and bird refuges and the General Land Office State maps should be consulted for these preserves, and their

boundaries should be verified by proclamations describing them or Executive orders modifying them. The word "preserve," "reservation," "refuge," or "range" should be used as appropriate.

*State parks and reservations.*—Names and boundaries of State parks and reservations should be verified by State publications and local information.

*Military reservations.*—Military reservations should be verified by reference to the General Land Office State maps and other general maps and through inquiry of the Corps of Engineers, War Department. The "List of military posts and camps in the United States" in the back of the Official Railway Guide should also be consulted.

*Power-transmission lines.*—Each topographic map upon which power-transmission lines have been shown and which is to be engraved for regular publication should be referred to the chief hydraulic engineer for his approval of the lines and designations for publication. For this purpose a colored pencil line should be drawn alongside each power-transmission line on an advance-sheet copy of the map.

*Comparison with other maps.*—The names and features on the topographic map that is being edited should be compared with the names and features as given by recognized authorities on general maps, in gazetteers, in reports of explorations, or in other available and appropriate reports. If discrepancies or unusual names or spellings are found, they should be questioned and if necessary letters of inquiry should be sent out. (See p. 334.) If it seems advisable cases should be prepared for consideration by the United States Geographic Board. (See p. 326.)

*Water lining and tints.*—In general, water bodies are represented on engraved maps by water lining. Water lining should be engraved to continue with the trend of the natural shore line and not follow around artificial features. Water lining should be carried continuously through piers, wharves, or other artificial structures built over the water if the cultural feature is shown in solid black, but if the cultural feature is shown with an open outline, as for a large pier or wharf, the water lining should be broken at the feature.

On maps that carry under-water contours water lining can not be shown, and it is desirable, when practicable, to use a flat blue tint to represent the water surface. Whether the flat tint is used or not, however, interior water bodies should be water lined, and large rivers should be water lined as far as the vicinity of the under-water contours.

*Detailed examination of original.*—The original drawing should be examined in detail in order to see that elevations agree with contours, that the right contours are accented, that depressions are properly hachured, that there is an equable distribution and clear delineation



of elevations and contour numbers, and that all symbols are clearly drawn and in conformity with Geological Survey practice.

*Depression contours.*—The engraving of hachures for the identification of depression contours (see p. 296) should be confined to small depressions and to such larger depressions or parts thereof as can not otherwise be readily recognized as depressions by the contour numbering alone. In general, the engraving of hachures may be omitted from depression contours that exceed 1 inch in length on the publication scale.

*Punctuation.*—Periods are to be consistently omitted on all lettering within the margin of the map.

*Position of lettering.*—Names should be placed as specified below if they are legible when so placed; otherwise they should be moved to a position where they will be legible. If no such position can be found and no authorized abbreviation exists and there is no suitable substitute, the name may be omitted, but a position must be found for the name of every important feature.

All names should be so placed that they will be readable from the bottom of the map. Names that are lettered parallel to a meridian should read from south to north.

Names of places, public institutions, ranches, mines, and other lesser cultural features should be placed horizontally and so far as practicable to the right of the features to which they refer.

Names of ponds, lakes, islands, swamps, and glaciers should be placed horizontally and to the right of the features named, unless the area of the feature is so large that the space will accommodate the name within its limits. Names of oceans, bays, coves, fiords, and straits should be placed across these features in broad curves.

Names of broad, water-lined streams should be placed within those features. Names of small shore features, such as points, should be so placed as not to touch the shore line and placed on the water side so far as practicable.

Names of railroads, highways, roads, trails, canals, and streams should be placed on the upper side of the feature wherever practicable and approximately in the middle third, but if the middle third does not cover the feature sufficiently to make the application of the name clear the same name should be shown in two or more places.

Names of narrow valleys, canyons, gorges, gulches, arroyos, and washes should follow the general trend of these features in easy curves and be placed preferably on the upper side. Where the limits of such features may be obscure the names should be so placed as to show the limits so far as practicable.



*Abbreviations.*—The following are authorized abbreviations:

Aux Mer	Auxiliary meridian.	Mdw	Meadow.
Ave	Avenue.	Mer	Meridian.
BM	Bench mark.	Mid	Middle.
Bdy	Boundary.	Mi	Mile.
Br	Branch, bridge.	MP	Milepost.
Bk	Brook.	Mil	Military.
Bu	Butte.	MM	Mineral monument.
Can	Canyon.	Mon	Monument.
C	Cape.	Mt	Mount.
Cem	Cemetery.	Mtn	Mountain.
Ch	Church.	Mts	Mountains.
CGS	Coast Guard station.	N, Nat, Natl	National.
Cor	Corner.	N	North.
Co	County.	No	Number.
Cr	Creek.	Par	Parallel.
Dist	District.	Pk	Peak.
Div	Division.	Pen	Peninsula.
E	East.	Pt	Point.
El	Electric, elevated.	Pd	Pond.
Elev	Elevation.	PO	Post office.
Fy	Ferry.	PH	Power house.
Fd	Ford.	Prin Mer	Principal meridian.
F, For	Forest.	RR	Railroad.
Ft	Fort.	R	Range, river, run.
G Mer	Guide meridian.	Res	Reservoir, reserva- tion.
Gl	Glacier.	Rd	Road.
Gl	Gulch.	Rk	Rock.
Gh	Gulch (in Alaska).	Sch	School.
Hbr	Harbor.	Sec, Secs	Section, sections.
Hdqrs	Headquarters.	Sd	Sound.
HW	High water.	S	South.
Hy	Highway.	Spr	Spring.
Hol	Hollow.	Std Par	Standard parallel.
H	House.	Sta	Station.
I, Ind	Indian.	Str	Stream, strait.
I	Island.	St	Street.
Is	Islands.	T	Township.
Junc	Junction.	Val	Valley.
L	Lake, or little.	VA	Vertical angle.
Ldg	Landing.	WT	Water tank.
Lt	Light.	WW	Waterworks.
LH	Lighthouse.	W	West, water.
LM	Location monument.		
LW	Low water.		

For abbreviations of State names see the Style Manual issued by the Government Printing Office, or the Geological Survey pamphlet "Suggestions to authors."

*Selection of elevations for engraving.*—The editor should select elevations for engraving on a basis of a spacing of about 1 inch apart on the scale of publication. He should be guided by the field instructions for "useful elevations" (p. 241) and should exclude all elevations for which the point of application appears to be indefinite. Preference should be given so far as practicable to important crossroads and road intersections, points in the vicinity of schoolhouses, and prominent summits. The elevations selected for engraving should be added to the new lettering tracings.

*Position of bench-mark letters and figures.*—Where practicable the letters "BM" should be placed above and to the left of the cross indicating a bench mark, and the figures of elevation below and to the left. Otherwise the letters may be placed to the right, above the figures. Different arrangements may be controlled by circumstances. If the bench mark is in a town or city and the lettering and figures can not be legibly placed near the position for the bench mark, the letters "BM" and the figures of elevation should be arranged in one line and inclosed in parentheses and placed directly under the name of the place. Figures of elevation for a supplementary bench mark should be placed to the right of the cross and above rather than below.

*Position of elevation figures.*—Of first importance in placing figures of elevation is the identification of the feature for which the elevation is given. Although a rule may apply where both identification and legibility are obtained, another position must be sought if either is uncertain; and unless a position can be found where both tests can be met the elevation figure should be omitted. Elevation figures in cities and areas of heavy culture should therefore be omitted unless the scale of the map permits their insertion.

Elevation figures for road corners and peaks that are named should be placed to the left of the feature; those for an unnamed road corner should be placed in the northeast corner, and those for an unnamed summit to the right. Figures showing water-surface elevation should be placed on the pond, lake, river, or other water feature shown.

*Position of contour figures.*—The purpose of contour figures being to facilitate the reading of elevations as expressed by contour lines, they should be placed at or near such critical places on the contours as the tops of ridges, saddles, the bottoms of valleys, and noticeable changes in slope. On some long slopes they may be advantageously placed in rows but the rows should not become too prominent on the map. A contour figure should not be placed at the extreme end

of a contour adjacent to a road, stream, or other feature, and it is not necessary near a road corner or other feature of which the elevation is given. Additional contour figures should be placed in outstanding and conspicuous places and with such frequency as will enable a map user to read any contour without prolonged search for a reference contour figure. This readability may generally be obtained by placing numbers only on the heavy contours, but it will sometimes be advisable to place contour figures on light contours and on depression contours.

*Style of engraved lettering within the map.*—The final drawings and lettering tracings should be lettered mostly in slanting block<sup>5</sup> and italic. (See p. 304.) The styles of the corresponding engraved lettering are well understood by the engraver and need be specified by the editor only where a doubt might otherwise exist.

All place names and names of country post offices, railroad stations, country schoolhouses, churches, and ranches should be lettered in lower case roman. The size of the letters should be commensurate with the importance of the place. Large cities, State capitals, and county seats should be shown in roman capitals.

Names of civil divisions, such as States, counties, districts, civil townships, and land grants; and of reservations, such as national and State parks, forests, and game preserves, Indian and military reservations, should be lettered in roman capitals.

Names of routes of communication, such as railroads, highways, trails, and canals; of public works, such as bridges, ferries, fords, locks, tunnels, dams, and wharves; of public institutions, such as lighthouses, lightships, life-saving stations, universities, State hospitals, asylums, and city parks and cemeteries; and of mining features, such as mines, quarries, prospects, furnaces, and smelters, should be lettered in small slanting block capitals.

Names of small hydrographic features, such as creeks, branches, brooks, runs, streams, pocosins, ponds, glaciers, coves, marshes, swamps, and bogs, should be lettered in stump; names of large hydrographic features, such as oceans, large bays, straits, rivers, and lakes, should be lettered in italic capitals. The choice between stump and italic capitals will depend upon the relative size of the feature.

Names of hypsographic features, such as summits, peaks, hills, knobs, gulches, canyons, gorges, draws, arroyos, washes, and islands; and of land features along coasts, shores, or rivers, such as points, capes, and bends, should be lettered in upright block. Only features

<sup>5</sup> The terms used here to describe styles of engraved lettering have long been in use by engravers. "Block" is the style generally known to printers as "gothic," and "stump" corresponds to "lower-case italic."

of considerable extent or importance, such as plateaus, mountain groups, ranges, basins, and valleys, should be shown in capitals.

*Style of engraved marginal lettering.*—The quadrangle, State, and county names at the northeast and southeast margins of the map, the department and Geological Survey heading at the northwest margin, and the State or other cooperative heading at the middle of the upper margin should be lettered in finished hair-line capitals (with spurs). (See pl. 15.)

The credit and date of survey at the southwest margin, the projection and horizontal datum, the projection figures, the grid note and distances, and the edition date should be lettered in lower case hair-line block.

The contour interval and the words on the bar scales should be lettered in lower case roman.

The names of adjoining quadrangles and the sea-level datum should be lettered in stump.

Township and range letters should be lettered in upright block capitals.

The lettering for the magnetic declination diagram should be in hair-line block capitals.

*Style of figures.*—The styles of figures inked on the original or final drawing (see p. 304) conform only in general with the styles in which the corresponding figures are to be engraved, but as the engraved standards are well understood by the engraver they need be specified by the editor only in unusual or exceptional cases. The following are standard styles of figures for engraving:

On the black plate, elevations of bench marks, both permanent and supplementary, are engraved in upright block. Elevations other than bench marks, such as those at road corners and summits and on lakes, are engraved in slanting hair-line block. Section figures are engraved in upright hair-line block on standard-scale maps and in open block on large-scale maps. Numbers on boundary monuments are engraved in slanting block. Township and range figures are engraved in upright block. Projection and grid figures are engraved in upright hair-line block; two sizes are used for projection figures, those for degrees being larger than those for minutes. Figures that occur in marginal notes or as part of a name follow the style of the accompanying letters.

On the brown plate, contour numbers are engraved in small italic.

On the blue plate, under-water contour numbers are engraved in small italic. Contour numbers on glaciers are also engraved in small italic.

*Parts of quadrangles.*—On a topographic map that is published in incomplete quadrangle form the blank part of the map should carry an appropriate legend descriptive of the conditions applying to the



blank area, as, for example, "Preliminary edition, unsurveyed area," for an area not mapped on any scale and "This area is shown on the map of the Dinuba quadrangle, surveyed in 1916, scale 1:125,000," for an area that has been surveyed but of which the published map is on a different scale, usually smaller.

*Edited map to topographer.*—On the completion of the editing the jacket should be dated, indorsed "Edited," and initialed by the one editing, and then with inclosures (original, editing work sheet, etc.) referred back to the author topographers or inkers, that they may see the result of the editorial review and reply to any editing questions. (See "Editing questions," p. 321.)

*Letters of inquiry.*—Essential information that is not obtainable from author topographers or from office data should be sought through letters of inquiry to postmasters, local civil officials, or other authorities, on forms provided for the purpose.

*New lettering tracings.*—On the return of the edited map from the topographers, new lettering tracings should be made in order that the engraver may have lettering copy with the names in their edited positions. If the names have been inked on the original drawing the necessary changes will have been indicated in red ink on the editing work sheet. The figures of elevation that have been selected for engraving should be added to this lettering tracing.

*Instruction sheet for engraver.*—If the lettering is on the original map the editing work sheet becomes the instruction sheet for the engraver, but if new lettering tracings have been made the remaining engraving instructions, with outstanding notes and questions, should be transferred to a clean advance-sheet copy on which will be indorsed "New tracings are copy for names." All boundaries should be emphasized by colored pencil on the instruction sheet, a different color being used for each kind of boundary shown on the map and a key to the colors used being added in the lower right corner. The instruction sheet should be made complete copy for marginal lettering, scales, and notes, and the original drawing should be changed to conform, in order that there may be no misinterpretation of copy. All necessary engraving instructions should be indicated in red ink, and all notations in pencil (other than boundary data) should be disregarded by the engraver, as they are editor's memoranda only.

*Filing of editing notes.*—A file of "editing notes" arranged by names of maps should be maintained in which all correspondence or copies thereof pertaining directly to the editing of topographic maps should be assembled. In this file should be placed all appropriate memoranda affecting important matters under discussion or in dispute, so that such data may be readily accessible for use in the editing of adjoining quadrangles, in the editing of reprints, or in correspondence.

## APPROVAL AND TRANSMISSION FOR ENGRAVING

When the editing is complete and all outstanding questions affecting the engraving have been disposed of, the jacket, on which the entire contents should be listed, should be indorsed "Approved for engraving" and should be dated and signed by the chief of the section of inspection and editing, who is responsible for the submission of topographic maps to the engraving division as complete and adequate copy for engraving.

Maps edited and approved for engraving and previously authorized for engraving should be forwarded direct from the section of inspection and editing to the engraving division.

## EDITING OF CULTURAL REVISION SHEETS

## CHARACTER OF EDITING

The editing of cultural revision sheets consists largely of an examination of the copy to insure its proper presentation to the engraver, that he may clearly understand where changes are to be made in the plates. In general, the character of the editing should follow the outline given under "Editing of topographic maps" (pp. 320-334), but with the thought always in mind that changes in the plates should be called for only where demanded by the cultural revision or made necessary through changed practices since the first or some other prior edition of the map.

## ENGRAVING AND EDITING DOCKETS

Cultural revision sheets should be included in the annual engraving docket of topographic maps (see p. 321) and should be placed on the editing docket in the same way as new topographic maps (see p. 321).

## SCOPE OF EDITING

*Work sheet and instruction sheet.*—The editing work sheet should be an engraved copy of the latest print of the map, and on this sheet all editing notes and names should be placed in pencil. The final markings and instructions for the engraver should be indicated in red ink, on the map margin or on the face of the map as may be appropriate. The instruction sheet should be mounted before the final markings are added.

*Engraving of new black plate.*—If the corrections to the culture plate are numerous the unedited cultural revision copy should be referred to the engraving division to determine whether it is more feasible to make a new black plate than to correct the old one. If the old plate is to be corrected the correction copy should be confined to changes, but if a new black plate is to be made the editor should ask for an inked sheet showing all the culture, and when that is furnished the

"take out" sheet may be retired. The road-classification data for the red overprint should be filed for editing when the reprint nears publication.

*Editing of cultural revision.*—The editing of cultural revision sheets should, in general, follow the outlines given under "Editing for reprints" (p. 341) and described more in detail under "Editing of topographic maps" (pp. 320–335). (See also field instructions for "Revision of topographic maps," pp. 262–264, and "Inking of cultural revision sheets," p. 301.) The items that require especial attention are new names, changed positions of names due to new or changed cultural features, changes in reservation and other boundaries and names, features such as power lines and oil and gas wells that were not shown on the former edition of the map, and marginal notes. The entire culture of the map should be subject to editorial review.

If the black plate is to be corrected rather than reengraved, the revision editor should call for as few small or immaterial changes as practicable in the position or arrangement of names or notes that are already engraved. If, on the other hand, it is found expedient to reengrave a new black plate full advantage should be taken of the opportunity to recast the names, figures of elevation, and notes into the best possible positions.

### ENGRAVING OF TOPOGRAPHIC MAPS

The topographic maps listed in the annual engraving docket (see p. 321) are engraved on copper in the engraving division of the Geological Survey. For each map three plates are engraved, one for each of the three principal colors of the printed map—a culture plate for the features and names that are to be printed in black, a relief (contour) plate for the features that are to be printed in brown, and a drainage plate for features that are to be printed in blue. These plates are sometimes referred to as the black, brown, and blue plates, respectively. Transfers are afterward made from the three copper plates to three lithographic stones, from which the maps are printed. Features subject to frequent change, such as national-forest boundaries and forest names, are not engraved on copper but are added to the stone by separate transfers from type and by handwork.

*Transmission for engraving.*—When the editing of a topographic map is complete and all questions have been answered so far as is then practicable, the sheet jacket, on which is entered a list of the contents forwarded, should be indorsed "Approved for engraving"; this indorsement should also call attention to any special or unusual features of the engraving and should be signed by the chief of the section of inspection and editing, who should also initial subsequent indorsements covering the transmission of engraved proof and copy. All



engraving copy and proofs thereof should be transmitted direct to the engraving division.

*Engraving.*—A polyconic projection is constructed on each of the three copper plates on the scale of the map publication. The original drawing of the map that is to be engraved is photographed to the publication scale, and from the glass negative a contact print is made on a zinc plate, on which the map features are in the reverse positions to those on the original drawing. The map on zinc is transferred in turn to each of the three copper plates by means of wax impressions obtained on celluloid and burnished down on the copper plates, where the impressions are suitably fixed. Transfers to the copper plates are made in small sections at a time, usually by coordinate blocks, in order to distribute any small errors that may exist in the scale of the original map. The reproduction of the map that has thus been transferred to copper is reversed, and the engraver must do his work in that position.

The several map features are cut into the surface of the copper plates by the engraver, who uses the transferred lines as copy and gages the depth of the cut according to the width of the line desired on the printed map—for example, a heavy contour is cut deeper than a light contour. On the culture plate only those features are cut that are to be printed in black, on the relief plate only those that are to be printed in brown, and on the drainage plate only those that are to be printed in blue.

#### PROOF READING

*First plate proofs.*—On the completion of the engraving on the three copper plates “first plate proofs,” in black, are pulled from each of the three plates, are inclosed in the jacket together with the original map and all engraving copy, and are referred from the engraving division to the section of inspection and editing for revision.

The proof reader should first familiarize himself with the editor's special instructions to the engraver and should examine the proofs with these in mind. Each plate proof should in turn be compared in detail with the original map, and all corrections noted should be marked on the plate proof by drawing a red inked line to the border of the proof and there indicating by word or symbol or by both the nature of the correction necessary. This detailed comparison should be made house for house, bend for bend, contour for contour (including spacing), stream for stream, feature for feature, and symbol for symbol. If apparent errors are found in the original drawing they should be called to the attention of the editor of the map. In order that there may be no omission or repetition of comparison between proof and original, the proof sheets should be suitably penciled over and checked as the proof reading progresses, but notations for the engraver's attention should be made in red ink. Questions arising



in the interpretation of the original copy or outstanding editing questions should be brought to the sheet margin in pencil and referred to the editor. Proof readers should date and initial the jacket and also each plate proof read. The jacket should be indorsed "Approved for correction and second plate proofs" and returned to the engraving division. If a part of the map edition is to be overprinted in green to represent woodland areas, the woodland copy should be forwarded to the engraving division at this time.

*Second plate proofs.*—When the corrections called for on the first plate proofs have been made on the copper plates, a second set of proofs is pulled and referred for further revision. The second plate proofs are checked, usually by the reader of the first plate proofs, in order to see that all the corrections that were noted on the first set have been made.

At this stage the reader of the second plate proofs should mark in blue pencil on the proof of the culture (or black) plate such headings, names, boundaries, scales, and notes as have not been engraved and are to be added to the lithographic stones by a separate transfer.

All outstanding questions, including references to author topographers and outside letters of inquiry, should be cleared up at this time, as transfers will now be made from each of the three copper plates to the three stones from which the final map in colors is printed, and any further corrections must be made by hand to these stones and also to the copper plates for future use.

The reader of the second plate proofs should initial and date the jacket and also each proof he reads.

*Letter check.*—After the second plate proofs have been read another proof reader should make an independent check of all lettering and elevation figures and should also initial and date the jacket and the proofs so read. This duplication in proof reading is justified because the names and numbers on a map are the features best understood and therefore most used and because experience has shown that a letter check is necessary. On the completion of the letter check the jacket should be indorsed "Approved for correction and combined proofs" and returned to the engraving division. If woodland is to be shown by an overprint in green the indorsement should also include the request, "Submit woodland proofs." If a road classification is to be overprinted in red the indorsement should include the request, "Submit two faint-blue prints of the culture mounted on zinc."

*Third plate proofs.*—Third plate proofs are requested only when the copy is unusually intricate.

*Separate stone proofs.*—Separate proofs from one or more of the printing stones may be requested, if the supplemental transfers to stone are unusually numerous or complex or if there are necessary corrections to the stones.

*Combined proofs.*—When the corrections called for in the reading of the second plate proofs and the letter check have been made on the three copper plates, transfers are made from each plate to three lithographic stones, and to these stones are also separately transferred from type impressions or from stock engravings such lettering, notes, scales, etc., as may not be engraved separately for each map. From these three stones, representing the culture, relief, and drainage features of the map, are printed combined proofs in the colors to be used on the published map (pl. 17). Combined proofs should be examined for completeness and especially for register and for all data added to stone after transfer from copper. The reader of the combined proof, who is preferably the reader of the first and second plate proofs, should initial and date the jacket and the proof. (For approval for printing see p. 340.)

*Woodland proofs.*—A proof of the woodland overprint is submitted on a combined proof of the map and should be read for completeness of copy and register, the woodland tracing registered over the original drawing being used as copy. The woodland proof should be initialed and dated by the proof reader.

#### ROAD-CLASSIFICATION COPY

From the road-classification sheets and data submitted by field topographers or others, and after an examination of available reference road maps, the map editor should prepare one or more road classifications based on existing instructions; such classifications should be drafted in black on faint-blue prints of the culture on paper mounted on zinc as photolithographic copy for printing. The marginal lettering required should be printed from type and pasted on the mounted sheet in the form of labels. (See p. 309.)

#### SIZE OF EDITIONS AND SPECIAL PRINTS

The chief engraver submits a combined proof of each new topographic map to be printed to the chief of the division of distribution for indication (on the margin of the map) of the size of the edition desired. The chief of the division of distribution transmits it to the chief of the section of inspection and editing, who should indicate on the same proof the proportion of the edition to carry the woodland overprint, or, if no woodland edition is to be printed, should so state.

The proportion of the edition to be overprinted in red with one or more road classifications should be determined by the chief of the section of inspection and editing and so indorsed on the proof above referred to.

A combined proof of each new topographic map is submitted by the chief of the section of inspection and editing to the chief geolo-

gist, for indication of the number and kind of special prints desired. This request is then inclosed in the jacket, for information of the engraving division when the map edition is run.

### APPROVAL FOR PRINTING

When all final proofs, including the woodland proof, have been read and when the road-classification copy for a red overprint has been prepared and the sizes of the several editions determined, the jacket should be indorsed "Approved for correction and printing, with woodland and road classification" [second clause omitted if not appropriate], dated, and signed by the chief of the section of inspection and editing.

The jacket, with inclosures, should then be transmitted direct to the engraving division for final correction, preparation of the printing plates, and printing.

### REPRINTS OF TOPOGRAPHIC MAPS

#### GENERAL FEATURES

*Distinction between reprint and new edition.*—The topographic maps are reprinted from time to time as the map-room stocks become exhausted. A topographic map that is reprinted without change or is reprinted with a few changes that are of a routine nature only and do not involve extensive corrections is designated a "reprint"; but a reprinted map that is materially changed, with the addition of considerable new information, or is altered by means of extensive corrections is designated a "new edition."

The designations of the several editions and reprints should be stated at the lower right-hand corner of the sheet. "Edition of ——" should be used for the first edition of the map, the blank being filled by the year, but not the month, in which the map is printed. "Edition of ——" should also be used for a new edition of the map, the date being changed. "Edition of ——, reprinted ——" should be used for all reprints, the dates being those of the last previous edition and of the forthcoming reprint.

*Correction files.*—A file of correction material for use in reprints should be maintained in the section of inspection and editing, and the corrections filed should, so far as practicable, be confined to those that can be approved at the time of filing. The practice of filing a map correction that may be incomplete or of doubtful value or application and marking it "To be considered at time of reprint" should be avoided if possible; the correction should preferably be fully examined when it is received and when the facts are fresh in mind and at that time prepared for future reprint use and approved, or, if found unavailable, disapproved and discarded.

*Requirements for corrections.*—Corrections to topographic maps are received by the Geological Survey from many sources. To be acceptable a correction must be specific and complete in itself; it must be complete as to the need for a rearrangement or omission of adjacent features; it must contain sufficient data upon which copy can be prepared for the changes in the copper plates; and it must be based upon authentic sources of information. In general, unless a correction is small or is of a simple nature, it can be satisfactorily prepared only by the employment in the field of means that are commensurate in accuracy with the methods used in the original survey for the map. With these requirements few outside engineers can comply, and therefore many corrections fail of approval.

*Stock lists.*—Stock lists, serially numbered, are prepared periodically in the division of distribution and list the topographic maps and other topographic publications of which the supply is nearly out of stock. Each stock list also gives the size of the reprint edition needed to supply the expected demand for each map listed, as estimated from recent sales and determined by current Geological Survey policy. Such stock lists, after administrative approval, are referred to the section of inspection and editing for the preparation and editing of copy for reprint. Each stock list is accompanied by two copies of the map to be reprinted.

*Reference to geologic branch.*—A carbon copy of each stock list together with one copy of each map listed on it, is referred by the chief of the section of inspection and editing to the chief geologist that he may indicate the kind and number of special prints desired when the edition of the reprint is run. A carbon copy of each stock list is also referred to the chief of the section of geologic maps for the preparation of a marginal note, if appropriate, to describe the geologic publications that treat of the quadrangle.

#### EDITING FOR REPRINTS

*Character of editing.*—The editing for reprints should consist in an examination and appraisal of the corrections on file and in the preparation of engraver's copy for such of the corrections as have been or can be approved. The reprint editor should also carefully consider the advisability of the changes that are described below under separate headings and should raise all questions that Geological Survey policy may suggest for consideration and decision in respect to the map that is up for reprint.

*Work and instruction sheets.*—The latest print of the map should be used as a work sheet upon which to assemble the changes that are contemplated for the new printing. The reprint instructions for the engraver should be written on the margin of a separate copy of the



same map, in red ink for plate changes and in colored pencil for stone work. Corrections and additions to the topography may be drawn on the instruction sheet or attached to it as separate copy. A filed correction that constitutes adequate copy for the engraver should be used rather than a copy made from it.

*Borders.*—The names of adjoining quadrangles that have been surveyed since the last printing of the map should be added. Border corrections that are on file should be carefully examined, and where additional drafting is needed it should be requested. Border-correction copy must be complete for all the copper plates involved and must include the marking of the "take outs," as this is necessary information for the engraver. "Take outs" should be indicated on a printed copy of the map. Border corrections that are small or of a simple nature may be drafted on a printed map and inked in one or more distinctive colors, but large or intricate corrections must be inked in standard colors on a tracing. Border corrections may be made on the scale of publication or on the scale of field work but must be accurately registered over the nearest projection corners. (See "Border corrections," p. 302.)

Attention should be given to the horizontal datum and to the possible need for dotted projection corners to join maps of adjacent areas, with an accompanying explanatory note.

*Filed corrections.*—Corrections, whether additions to the map or changes in features already shown, must subscribe to the requirements for corrections given on page 341. If the information given is complete but the drafting is deficient the correction should be referred for proper drafting. Inasmuch as the correction files contain some correction material the use of which can not be approved, for reasons of expediency, the reprint editor should seek administrative approval before considering the use of any correction material of doubtful value. The corrections themselves may be drawn on the printed map provided they can be made legible; otherwise the correction copy should be drawn on tracing cloth registered over the map. Corrections that are drawn on a printed map must be indicated in distinctive colors that are readily distinguishable from the lines of the map, but corrections that are shown on a tracing should be inked in the standard colors used for topographic map drawings.

*Geographic Board decisions.*—The section of inspection and editing should maintain a State and county list of Geographic Board decisions, and each new decision that affects a name shown upon a published Geological Survey map should be entered in the correction files. Board decisions that have been made since the last previous printing of a map should be applied to the next reprint.

*Reservation boundaries.*—Corrections should be made to show changes in boundary lines or names of national forests, national

parks, national monuments, and Indian reservations. If such boundaries and names were not shown on the last printing of the map they should be added, and for that purpose the map should be referred for the needed plotting. All reservation boundaries and names should be thoroughly checked for each reprint.

*Public-land lines.*—Land lines that have been surveyed by the General Land Office since the prior printing of the topographic map should not, as a rule, be added to reprints, for the reason that they can seldom be properly tied to the topography, and their adjustment may entail more office work than can be expediently provided for. Where an office adjustment is practicable, however, and where important joining with other work is involved a small amount of such additional engraving may be requested. If addition or change of a public-reservation boundary is involved it may be necessary to adjust a provisional land net on the map in pencil as a base upon which to construct the new boundary.

*New or changed notes.*—The following marginal notes should be added to reprints provided they were not carried on the previous edition of the map: Polyconic projection; North American datum; statement of direction and amount off North American datum if not on North American; statement of the correction necessary to place the vertical datum on the latest adjustment to mean sea level; quadrangle and State name in lower right-hand corner; magnetic-declination diagram; long bar scale of miles on east margin of map; and any other note or legend needed to explain a new or changed condition on the map. (See "Marginal lettering," p. 305, for the positions of many of these items.)

*Cooperative headings.*—A cooperative heading that has been used on the first edition of a topographic map may be used for a reprint of the same map provided the identical cooperation is still in effect under the same officials. This condition, however, seldom exists, and as a consequence many forms of cooperative reprint headings are needed. The following arrangements of reprint headings should be used when the conditions specified exist at the time of reprint.

(a) If there is present cooperation with the original cooperating body but with different officials, use the original heading with the names and titles of officials omitted. If the designation of a public office, as governor or State engineer, should be retained in order to identify the former cooperation, the heading may be supplemented by such an expression as "Represented by the governor [or the State engineer]."

(b) If there is present cooperation with the same officials or their successors but under a reorganization, use the form "Represented by the ————," supplying the name of the new body and omitting the names and titles of officials.

(c) If there is no present cooperation but the original cooperating body is still in existence, use the original heading with the names and titles of officials omitted, whether the same or successor officials are in office.

(d) If there is no present cooperation and the original cooperating body is not in existence, use the original heading with the names and titles of officials omitted.

(e) If there is no present cooperation and the original cooperating body has been reorganized under the same or successor officials, use the reorganization name in the form "Represented by the \_\_\_\_\_," but omit the names and titles of officials.

*Outside credit.*—Credit for material additions to the topography derived from sources outside the Geological Survey should be given in a footnote, in the form, "Roads and trails added 1920 by National Park Service."

*Woodland.*—In general, a woodland edition is printed only for the first edition of the map. Where the woodland copy fairly represents the conditions at the time of reprint, however, the woodland may be again overprinted. The reprint editor should ask for instructions in all appropriate cases.

*Correspondence.*—If doubt exists as to the correctness or appropriateness of a reprint correction and if information can be obtained through correspondence, letters of inquiry should be sent out, forms provided for the purpose being used if practicable. Such inquiries, however, should be made far enough in advance to avoid unnecessarily delaying the reprint and should preferably be made when the correction is first received.

*Approval of reprint copy.*—When the reprint manuscript is complete and in proper form as copy for the correction of the copper plates and printing stones it should be approved and forwarded to the engraving division. The reprint copy for each map should be indorsed "Approved for correction" and dated. The indorsement should also request such plate, stone, or combined proofs as may be needed for the proof reading of the corrections before the map is printed and should list all special prints needed by other branches of the Geological Survey. When as many maps on a stock list as can be conveniently prepared at one time are ready for transmission, these, together with the stock-list letter appropriately indorsed, should be forwarded to the engraving division. Further transmissions of delayed reprint copy for maps on the same stock list should be forwarded singly from time to time as the copy can be prepared.

Transmissions, approval of corrections, and final approval for printing should be made by the chief of the section of inspection and editing. Recommendations affecting a change in the size of a reprint



edition or the cancellation of a reprint should be made through the chief topographic engineer.

*Proofs and proof reading.*—Each proof that has been requested will, upon submission, be read and afterward returned to the engraving division with indorsements for further action. When all corrections have been made the reprint material should be indorsed "Approved for printing." Successive indorsements should be made in sequence on the margin of the engraved map that is used as the base correction copy.

## PREPARATION OF RIVER SURVEY MAPS FOR PHOTOLITHOGRAPHY

### REPRODUCTION

The plan sheets and profile sheets of the river surveys are not engraved on copper but reproduced by photolithography on the field scale, in one, two, or more colors. In general, a small edition of advance sheets is printed in black, and this edition is followed by such regular publication as may be decided upon for each project, in two or three colors as may be found expedient.

### INKING OF FIELD SHEETS

The field plane-table sheets should be inked in standard colors; all the drainage and culture should be inked, but only so much of the contouring as can be clearly read on a reproduction by a single-color photolithograph.

Free-hand inking must be done in sharp, fine dark lines, suitable for clear reproduction by photolithography, and right lines may need to be twice lined if fine or in color. As it is the readability of the contours from the engineer's point of view that is desirable rather than their graphic expressiveness of relief, the inking of contours that closely parallel any shown drainage or culture should in general be avoided. Numerous contour figures should be added, and location crosses with figures of elevation should be inked for such exterior points as are instrumentally determined.

*Water-surface crossings.*—Water-surface contour crossings must be drawn heavy and solid from shore to shore. Every fourth contour crossing, where the contour interval on land is 20 feet (or intermediate crossings if spaced far apart), must have its elevation placed at the outer end of a black right line drawn out clear of all topography.

All water-surface elevations should be inked on the outer edge of the topography, in red, for sheet record only; accompanying reference or direction lines should be inked in red but should be kept clear of all topography. Such data are not intended for final printing and should be brushed out on the negatives.



*Land lines.*—Land lines must be drawn solid, and township lines emphasized. Only such section and township lines should be inked as the Land Office plats or notes show have been run and have not since been suspended. Section numbers must be shown only where land has been sectionized; they should be drawn preferably at the centers of sections but should be offset from the center if necessary to gain legibility.

The entire land net should be checked against the land plats before the land lines are inked.

*Rapids.*—Rapids should be inked in the conventional symbol, but the inking should be so spaced that it will not obscure the contour crossings or other important river data.

*Other features.*—In the inking of other map features found on river-survey sheets the inker should be guided by the instructions given for the inking of the corresponding features on topographic maps.

*Mileage.*—Before the field sheets are cut and assembled into plan sheets, the mileage must be plotted by pivoting and swinging a scale of miles (drawn as a straight line on tracing paper) within the channel; it must not be stepped off with dividers. The same tracing should pick up the contour crossings for subsequent plotting on the profile sheets. The mileage should not be inked until after the field sheets are assembled into plan sheets.

*Inking of intermediate contours.*—All intermediate contours should be omitted in the inking wherever they are closely spaced or where their spacing between the heavy contours is even. This omission is required because closely spaced lines will run together in a photolithographic reproduction and because the needless cost of such inking should be avoided. An engineer values a contour map for its readability in terms of elevation rather than for its expressiveness of shaded relief.

#### SIZE OF SHEETS

Sheets showing river surveys are of uniform size (22 by 29 inches), with all plan or profile work kept within an 18 by 25 inch neat line, which should be drawn with margins of 2 inches on all sides. Marginal lettering should be kept within as short a vertical space as possible.

Double-mounted drawing paper, cross sectioned in light blue within an 18 by 25 inch neat line, is carried in stock and will be found convenient for use for plan or profile sheets. It is divided into fifths of an inch horizontally and quarters of an inch vertically, thus giving tenths of a mile on a scale of 2 inches to 1 mile (1:31,680) and convenient intervals for profile construction.

## PLAN SHEETS

*Assembly of field sheets.*—The field plane-table sheets must be peeled from the cloth (see p. 283) and by means of cutting and pasting assembled within the 18 by 25 inch neat-line limits of the plan sheets. Before the field sheets are peeled, however, azimuth lines must be transferred to enough places on each field sheet to permit the placing of each patch in a correct azimuth on the plan sheet. The azimuth used should be that of true north.

The plan should be assembled in as few and in as continuous stretches on the same sheet as is practicable, and these stretches should be condensed within the sheet so far as the necessary allowance for outlying section lines, lettering, and other markings will warrant. Space must be left for the key map on each sheet.

Immediately after the patches are pasted on the plan sheets the sheets should be placed flat under heavy weights and allowed to dry under pressure for one and preferably for two days.

*Joining lines.*—When the field sheets have been cut and pasted, joining lines should be inked as right lines at both ends of the cut, and the two ends that join should be lettered identically—A-A for the first cut, B-B for the second, etc. When the alphabet has been exhausted double letters should be used, as AA-AA, BB-BB.

*Mileage.*—The plotting of all mileage (see p. 346) must be independently checked before it is inked, as an error afterward discovered necessitates moving all mileage marks that are beyond the one erroneously plotted. An error in the plan-sheet mileage would also correspondingly affect the profiles.

Distances along the river should be indicated in black by figures within small circles placed at the ends of right lines drawn clear of all topography from the center of the stream opposite each plotted mile of channel flow. The circles should be placed on the same side of the stream for as long stretches as is feasible, for greater convenience in finding and reading, but this practice need not be followed if it would result in crowding and a better location for the circle can be found in a more open place. Preferably, the circles should be numbered upstream.

The uninked right lines that pass over the inked topography are drawn in on the glass negative later.

*Boundary lines.*—The inking of county, national forest, and other boundary lines on plan sheets should be confined to the lines that fall within the zone of the survey and have been mapped in the field, and such boundary lines should not, in general, be extended beyond the inked topography, except for short distances for the purpose of keeping the necessary lettering away from the topography.

## PROFILE SHEETS

*Profile construction.*—Profiles should appear on separate sheets from the plans and should be drawn directly across the sheet, with the separate rows condensed as much as practicable. Their direction should be upstream as read from left to right, irrespective of easting or westing. Space must be left on each profile sheet for the key map.

For profiles uniform vertical scales should be used so far as possible, and profile angles in excess of  $45^{\circ}$  should be avoided. The profile should be constructed from the water-contour crossings, supplemented by elevations determined at the head and foot of falls and elsewhere. (See p. 267.) Profile lines should be drawn heavier than construction lines, and sharp angles should be slightly smoothed.

Before a profile is inked its construction must be carefully checked by a person who has not been engaged in its initial preparation.

*Profiles of tributaries.*—Wherever the profile of a tributary is steeper than the profile of the main stream above the mouth of the tributary, the profile of the tributary should be constructed as a branch profile leaving the main-stream profile at the junction point.

## KEY MAP

A key map must be prepared for each set of river-survey maps. This map should be carefully generalized from the detailed plats and should be compiled in pencil on any convenient scale that is somewhat larger than that of publication. The compilation can in general be best made on tracing linen and must be afterward traced and inked as copy for photographic reproduction. The prints should be made on paper suitable for reproduction by photolithography, and one print should be pasted on each plan sheet and one on each profile sheet.

As the prime requisite of a key map is legibility, the county and national-forest boundary lines may in general be omitted from it, but a boundary line that crosses the line of survey at or nearly at right angles may be shown.

The limits of the river survey shown on each separate plan sheet should be indicated on the key map by a connected series of rectangular blocks, the end lines of which cross the river at these limits. Each block on the key map should be marked with the serial letter corresponding to that used on the plan sheet represented. (See below.)

The title "Key map of plan sheets" should be placed under the key map.

## MARGINAL LETTERING FOR ALL SHEETS

All sheets of the plan and profile set should carry identical headings and other captions except where the data shown necessitate changes, such as different scales, contour intervals, authorship, and serial

sheet letters. The marginal lettering for plan and profile sheets should be printed from type impressions, and the printed labels should be pasted on the drawings in the positions that are indicated below. (See pl. 16.)

*Title.*—The title used to describe river-survey maps should be identical for all sheets of the set, including both plan sheets and profile sheets, and should be printed in capitals and placed in the center of the margin above the upper neat line. The title should give the names of the main streams shown and include the names of the larger tributaries that have been surveyed, but if these tributaries are too numerous, too little known, or unnamed, they may be referred to by the phrase "and tributaries" or "and other tributaries." The title should include the name of the State or States through which the river runs and the names of the places at the ends of the survey.

*Designation by serial letters.*—Each plan sheet and each profile sheet should be designated by a capital letter, as sheet A, sheet B, the first profile sheet being designated by the letter next following that used for the last plan sheet. The letter I should be used. This designation should be placed above the upper neat line and near the right-hand corner.

*Federal heading.*—The heading "Department of the Interior" centered above "U. S. Geological Survey" should be placed above the upper neat line and near the left-hand corner.

*Number of sheets.*—Under the lower neat line and near the right-hand corner should appear a statement in parentheses giving separately the number of plan and profile sheets—for example, "6 plan sheets, 4 profile sheets."

*Date of printing.*—Below the statement giving the number of sheets should be given the date of the printing of the edition—for example, "Printed in 1927."

#### MARGINAL LETTERING FOR PLAN SHEETS

In addition to the marginal lettering specified above all plan sheets should carry the marginal lettering described in the following paragraphs:

*Authorship, date, and cooperation.*—Under the lower neat line and near the left-hand corner should be placed, in separate lines, the names of the topographers engaged in the mapping, the date of the survey, and the names of the organizations, if any, cooperating in the work. (See pl. 16.)

*Scales.*—Under the center of the lower neat line the horizontal scale of the plan should be stated as a fraction, and directly beneath, on separate lines, should appear a bar scale of miles, a bar scale of feet, and a bar scale of kilometers.



*Contour intervals.*—Under the bar scales the statement “Contour interval on land—feet” should appear, and directly beneath it the statement “Contour interval on river surface—feet.”

*Datum.*—Under the statement of contour interval should appear the statement “Datum is mean sea level” or the appropriate statement if the river survey is referred to a vertical datum that differs from sea level.

*Horizontal adjustment.*—Inasmuch as river surveys are seldom horizontally controlled the plan sheets are generally subject to adjustment, and a statement to that effect should accordingly be placed under the lower neat line and a little to the left of the right-hand corner, unless the plan sheets are in true adjustment.

*Declination.*—Under the lower neat line and to the right of the bar scales should appear a diagram showing the magnetic declination, with date.

#### MARGINAL LETTERING FOR PROFILE SHEETS

In addition to the marginal lettering for all sheets described on page 348, all profile sheets should carry the marginal lettering given below:

*Horizontal scale.*—In general, the profile should be constructed on the same horizontal scale that has been used for the plans; and both fractional and bar scales should be placed on the profile sheets in the same positions as on the plan sheets.

*Vertical scale.*—Under the bar scales should be placed a statement of the vertical scale on which the profile has been constructed, in the form “Vertical scale 1 inch = 40 feet.” If more than one vertical scale is used on one profile sheet the separate parts of the profile that are drawn on differing vertical scales should be separated on the sheet by dividing lines, and within the borders of each divided section should be indicated its vertical scale.

*Datum.*—Under the vertical scale should be placed the same statement of vertical datum used on the plan sheets.

*No other marginal lettering.*—No statement of authorship, date of survey, or cooperation should be made on profile sheets.

#### HAND LETTERING

*Plan sheets.*—Lettering in general should not be placed on or within the inked topography but kept in near-by open spaces, so far as such spaces can be found. The lettering should be kept near the pasted map strip to which it refers and not be extended near an adjoining strip. Emphasis should be given to the names of the surveyed streams.

On each pasted patch covering a separate stretch of the river should be lettered the stream name and in addition township and

range numbers for identification. The joining letters at the ends of the patches should be inked in the sequence described on page 347.

Mileage and contour crossings should be inked as described for the penciling.

*Profile sheets.*—On each separate stretch of continuous profile, either for the main stream or for a tributary, should be lettered the stream name, above and parallel with the slope of the profile.

The names of only the larger tributary streams should be lettered on the profile sheets, but the names of all bridges, dams, dam sites, towns, falls, and well-known rapids should be lettered and placed vertically over the corresponding points in the profile.

#### STYLE OF LETTERING

*Marginal lettering.*—The styles of type that are in general use for the marginal lettering as designated in the engraving division type book (edition of January, 1926) are as follows:

Title, light copperplate gothic Nos. 5 and 6.

"Sheet A," etc., light copperplate gothic No. 7.

Federal heading, Celtic No. 1, 8 point.

Number of sheets, lining gothic No. 60, 10 point.

Date of printing, lining gothic No. 60, 8 point.

Authorship, etc., circular gothic No. 44, 10 point.

Contour interval and datum, circular gothic No. 44, 10 point.

"Subject to adjustment," lining gothic No. 60, 10 point.

Declination, lining gothic No. 416.

Title on key map, slope gothic No. 504.

*Hand lettering.*—The style of hand lettering for plans and profiles should be as follows:

Stream names, slanting block, capitals or lower case as appropriate.

Place names and topographic features, upright block, capitals or lower case as appropriate.

Falls, rapids, eddies, dam sites, power plants, and ranger stations, slanting block capitals.

County names and land-line information, upright block capitals.

Railroads, roads, road designations, and bridges, slanting block capitals (smaller than falls, etc.).

Reservations, national forests, etc., slanting block capitals.

Ranch and cabin names, upright block lower case.

#### PREPARATION OF DAM-SITE MAPS FOR PHOTOLITHOGRAPHY

##### REPRODUCTION

Large-scale dam-site maps are reproduced by photolithography on the field scale, in black only, in small editions for limited distribution; they are not included in the published series of plan sheets.

## INKING OF FIELD SHEETS

Dam-site maps should be inked in the standard colors and in general under the instructions prescribed for river-survey maps. (See p. 345.) As the scale is large all intermediate contour lines should be inked.

Section corners located within the area covered by a dam-site survey should be designated by the symbol for a found land corner, but in general land lines should be omitted from dam-site drawings, inasmuch as the field work within the small area of the large-scale survey seldom supplies enough data for the proper plotting of land lines on that scale.

A line should be drawn across the map to represent the proposed location of the dam. This line should be inked in black between the same limiting contours on the two sides of the stream at the site.

The elevation of the water surface at the proposed dam site should be inked.

## DAM-SITE SHEETS

*Assembly into sheets.*—Dam-site maps, after inking, should be assembled into sheets as described under "Assembly of field sheets" (p. 347), but space must be left between the separate dam-site maps for cross sections as described below. The sheets should be of the same size as those used for plan sheets. Dam-site maps should be pasted on the sheets in the same order in which the dam-site locations are found on the plan sheets, and they should be designated by the same mileage that is used on the plan sheets, expressed to the nearest tenth of a mile.

*Cross sections.*—Cross sections should be constructed for each dam site that is designated by the conservation branch. The horizontal scale should be somewhat larger than that of the dam-site map, and the vertical scale should be such as will give a profile that is neither excessively steep nor too flat and may average  $45^{\circ}$ .

The line of the first cross section should be designated A-B, the letter A being placed on the left bank and the letter B on the right bank, looking downstream. The cross section should be drawn with the left-bank side shown on the left-hand side of the drawing and the right-bank side on the right-hand side. Succeeding cross sections should be designated C-D, E-F, etc., double letters (AA-BB, etc.) being used if necessary.

## LETTERING

*Marginal.*—The marginal lettering for dam-site sheets should accord with the instructions for marginal lettering for plan and profile sheets (see pp. 348-350) save for differences in scales, contour intervals, and other data.

The title of the dam-site series should begin "Miscellaneous dam sites," and this phrase should be followed by a descriptive title, which may be identically the same as is used in the corresponding plan and profile set. The sheets of the series should be numbered instead of lettered, as sheet 1, sheet 2, and in the lower right margin, below the neat line, should be placed a statement of the number of the sheet in the set, as "Sheet 3 of 5 sheets." The statement "Subject to adjustment" should not be used.

The first line of the scale should read, for example, "Plan scale 1:2400, or 1 inch = 200 feet." Directly under this statement should appear a bar scale of feet, and below the bar scale a statement of the cross-section scales—for example, "Cross-section scale (horizontal 1 inch = 100 feet; vertical 1 inch = 80 feet)." Next below should appear a statement of contour interval. The statement of datum should appear on the last line and should be identical with the one used on the corresponding plan and profile set.

If more than one horizontal or vertical scale or contour interval is employed on a single dam-site sheet, the maps and cross sections of the dam site or sites using such differing data should be separated on the sheet by bounding lines inked in black, within which should be given all necessary data that can not be given at the bottom of the sheet as applying to the sheet as a whole.

*Hand.*—The dam-site plans should, in general, be lettered in the same way as the plan sheets of the plan and profile set. On the left and right-hand sides of the cross section should be lettered "Left bank" and "Right bank" respectively. Beneath the cross section should appear its designation—for example, "Cross section C-D (3.4 m.)," the mileage being expressed to tenths. Above the cross section should appear the name of the dam site, if any—for example, "Tully Rapids dam site." The name of the dam site and the mileage should also appear alongside the dam-site map.

## INSPECTION AND EDITING OF RIVER-SURVEY MAPS

### CHECKING

*General character.*—The checking of river-survey maps should be based upon the instructions for the checking of topographic maps (p. 310) so far as they apply. Checkers of river-survey sheets should also be familiar with the instructions for river surveys (p. 266) and with the instructions for the preparation of river-survey maps for photolithography (p. 345) and the preparation of dam-site maps for photolithography (p. 351).

*Plan sheets.*—If the mileage has been checked before inking it should need no further checking. All figures of elevation, whether land or water contour, bench mark, or useful elevation, should be



checked and compared with the contouring. The separately pasted patches of topography should be tested at their joining edges for azimuth and matching. The entire land net shown on the plan sheets should be checked. The entire drawing of each sheet should be examined for completeness. The river-survey sheets should be compared with maps representing any previous surveys inclosing, crossing, or adjacent to the new survey, and attention should be called to discrepancies that may affect the new river survey or any previous work on the same or any similar scale.

*Profile sheets.*—If the profiles have been compared with the plan-sheet contour crossings and checked before they were inked they should need no further checking. The mileage figures and the profile elevation figures should be checked for sequence and correct application. The names of the river features that have been selected to appear on the profile sheets should agree in spelling, point of application, and mileage with the corresponding names on the plan sheets.

*Key map.*—The key map, having been previously edited before photography, should need no further examination in the checking. (See "Editing," below.)

*Checker's signature.*—The checker's signature and all further signatures should be placed upon sheet A of the series and should be understood as applying to the set as a whole.

#### INSPECTION

The inspection of river-survey maps should be based upon the instructions for the inspection of topographic maps (p. 313) so far as they apply, and also upon a familiarity with the instructions for river surveys and their office preparation for photolithography. The inspection should also be made with reference to legibility and the use of the maps by engineers.

#### EDITING

*Character of river surveys.*—The editing of river survey sheets (see pp. 266, 345) should in general be restricted to plan and profile sheets that are to be issued as sale publications. River-surveys sheets that are to be issued only as advance sheets in one color and sheets of miscellaneous reservoir and dam sites should be edited only under exceptional conditions.

*Character of editing.*—River-survey plan and profile sheets should be edited for completeness of copy, spelling, agreement of names, and other features with those shown on other reliable maps, including Geological Survey maps if the area has been previously surveyed, correct sequence of mileage, and boundaries falling within the limits of the river survey. The key-map tracing should be edited

before it is photographed for the several sheets, and the title for the series should be edited before it is printed. The names that are shown in common on the plan and profile sheets should be compared for agreement in point of application as well as in spelling. Features of a doubtful nature should be questioned.

#### EDITING OF STATE INDEX CIRCULARS

*Character of index circulars.*—Index circulars are issued for each State or small group of States to show the progress of topographic and geologic mapping. The base map that is used is either a photolithographic reduction to a scale of 1:1,000,000 of the 1:500,000 State map or a transfer from a United States base map. This base is printed in gray in order that the outlines and names of the quadrangles that have been surveyed and published may be legibly overprinted in red. The back of the circular carries a description of the character of topographic maps, geologic maps, and river surveys, descriptions of special maps that are either not indicated or not sufficiently indicated by the red overprint, lists of other publications covered by the several Geological Survey activities within the State, a list of libraries where these publications may probably be consulted, and a list of authorized agents selling the maps of areas in their vicinity. Index circulars are frequently revised in order to show current progress in mapping and are issued free on application to the director.

*Printing of index circulars.*—The base for an index circular may be printed from plates on hand, without correction, from old plates after correction, or from new plates. For the correction of old plates or for the making of new plates correction copy or a new base must be prepared. The red overprint may be printed from old plates after correction or from new plates made from new copy.

*Stock lists.*—As the stocks of index circulars are exhausted they are reprinted and brought up to date under the authority of stock lists. (See p. 341.) Each separate index circular is placed upon a separate stock list.

*Character of editing.*—The topographic editing of an index circular should be confined to the base map and the red overprint. So much of the red overprint as applies to geologic folios is edited by the editor of geologic maps and the text part of the circular is edited by the editor of texts. The topographic editor should appraise the base map that was used for the last edition of the circular, as to its present correctness of data, such as county lines; inquire as to the condition of the printing plates in case the old base is to be reprinted; consider the availability of any new base, whether a reduction from a new or revised State map or a transfer from a new United States map; consider the amount of addition or change to the old red overprint plates,

and inquire into their condition in case the corrections can readily be made on them, but otherwise prepare the copy for a new plate. The further editing should consist in preparing the appropriate copy and instructions for the engraving division for use in reprinting the circular.

When new bases become available consideration should also be given to the practicability of changing an index circular representing a group of States into separate index circulars for each State in the group.

If reductions to a scale of 1:1,000,000 of the State maps of the 1:500,000 series are used as bases for index maps consideration should be given to the date of the latest revision or new compilation of the State map, and the advantages of such a base should be listed and instructions sought as to its possible use. Particular attention should be given to the accuracy of county lines and the showing of new counties as they are created, inasmuch as many inquiries are received concerning areas within a specified county.

*Work sheet.*—The work sheet for the red overprint should be a copy of the latest index map, on which the names of newly printed maps and newly surveyed quadrangles should be indicated in pencil.

*Preparation of reprint copy.*—Instructions should be prepared for the use of the engraving division stating specifically what base is to be used for the new edition of the index circular; and if a new or corrected base is required the proper copy should be specified or prepared. The quadrangle outlines for the red overprint copy should be drafted in solid black lines on a faint-blue photolithographic reproduction of the base that has been printed on mounted drawing or chart paper, on the scale of publication of the index map. Quadrangles that have been mapped to the State line only, whether in the State for which the index is being prepared or in an adjoining State, should be shown as mapped, with a solid black line along the State boundary. The names of quadrangles and the notes that are to be printed in red should be printed from type and pasted on the copy in proper positions. Information as to the progress of new surveys should be taken from the general progress book that is kept in the topographic branch, and this should be further verified by inquiry in order to provide for the plotting of all quadrangle maps which have been completed or whose completion can be safely estimated. Publication of a map should not be anticipated by more than three months unless approved by the division of distribution.

*Approval and transmission.*—Copy for index circulars should be approved by the chief of the section of inspection and editing and by him forwarded to the engraving division for correction and printing. Combined proofs should be asked for, corrected, and returned with approval for the printing of the edition.



## EDITING OF ILLUSTRATIONS

*Kind of illustrations edited.*—The reports of the Geological Survey on the many phases of geology, including mineral resources, water supply, conservation, and other subjects, carry many illustrations such as maps, charts, diagrams, and sections. These illustrations are of great variety, ranging from details on large scales to small maps covering large areas on small scales and including both general maps and conventional base maps; but whatever their kind, most of them are designed or adapted to serve the single purpose of the paper they illustrate. Most illustrations are prepared in the section of illustrations, although some are prepared in the separate branches. Proposed illustrations that are topographic or geographic in their nature are referred to the section of inspection and editing for examination and editorial approval before publication.

*Need for topographic editing.*—Illustrations are edited from a topographer's viewpoint in order to make them as accurate, legible, and presentable as the character of their compilation and their purpose permit. Inasmuch as such illustrations are largely special-purpose maps they are not required to have the balance and finish of permanent maps, but they are required to withstand the tests of reasonable criticism.

*Scope of editing.*—The editing of a map illustration should determine whether it is suitable for its purpose and of the best possible quality, limitations of time and cost considered; should assure its freedom from errors and important omissions; and should include an examination for legibility, both in execution and in the choice of symbols. Consideration should also be given to a comparison with other maps and publications covering the same area, both for accuracy and for cross reference. Geographic names should be edited for their propriety, spelling, placing, and comparative prominence. Projection and elevation figures, land-subdivision designations, scales, and other details should be verified. Topographic representation, even though sketched or approximate only, should be free from error or inconsistency of expression.

## EDITING OF STATE MAPS

*Character of State maps.*—The State maps to be edited (see p. 360) are those of the 1:500,000 series, new compilations and revised editions of which are issued from time to time. The State maps are published in one or two colors as conditions warrant; if two colors are used the drainage and drainage names are printed in blue. The manuscript maps that are to be edited are compiled on a scale of 1:500,000 and are reproduced by photolithography on the same scale.

*Character of editing.*—Inasmuch as the corrections called for by the editor will have to be made on the original drawing itself, for the



reason that this drawing is the camera copy for the reproduction of the map, the original drawing should be so carefully prepared that the editorial corrections will be largely in the nature of details and of such a character as can be readily made on the original drawing. There should therefore be a cooperative understanding between the cartographer and the editor to the end that the general plan of compilation may conform to the desired standards, leaving to the editor only a checking up of such details as may escape the cartographer, who is fully occupied for the time being with the task of compilation.

The editing should consist in an examination of the original drawing for completeness of representation, adequacy of the drafting for photolithographic reproduction, proper distribution of the features shown, and correct spelling of the names shown. The correct reduction and transfer of the map material that has been used should be assumed to have been properly done, unless a casual examination discloses otherwise. Data of a general nature, however, such as postal, railroad, and public-land line data and boundary lines, should be verified by the editor.

*Editing marks and corrections.*—The editing notations should be made in such a way as not to injure the original drawing and may in general be indicated in light pencil on the map margins. Where the copy is intricate or the changes appear to be numerous, however, a photostat copy of the original should be requested, and this copy may be made on any convenient scale.

*Editing in detail.*—In verifying the data shown on the State map reference should be made to the instructions for the corresponding features on topographic maps (pp. 320–334). Many of these instructions may not apply to the State map in hand because of the absence of relief, smaller scale, or different form of publication, but in general they will serve as a useful guide. Features of especial importance to be examined are the names and boundaries of counties; national and State forests, parks, and reservations; place, stream, and railroad names; titles; and scales. The published maps of the Geological Survey should receive consideration as maps that have themselves been edited, but allowance should be made for changes subsequent to publication and for the more thorough examination that has been given to maps of a more recent date.

#### EDITING OF UNITED STATES MAPS

*Character of United States maps.*—The character of the maps of the United States published by the Geological Survey is described in each of the State index circulars. The maps are published on several scales, ranging from 40 to 260 miles to 1 inch. As the scale decreases the character and amount of detail that can be legibly shown decrease correspondingly. United States maps are compiled and drawn on

scales slightly larger than the scale of publication and are reproduced by engraving.

*Character of editing.*—Editing notes can usually be most conveniently placed on a photostat reproduction of the original drawing. The editing, in general, should consist in a careful scrutiny of the entire map for completeness and consistency of representation and as adequate copy for the engraver; in an examination of the map for the proper distribution and selection of features and names to be shown; and in a review of all names for correctness of spelling and best arrangement. Legibility of the published map should be provided for, and where the data shown are found to be excessive for a clear reading of the printed map they should be reduced in amount.

*Proof reading of engraved maps.*—The plate and combined proofs of engraved United States maps should be compared with the final manuscript map that was submitted for engraving under the same general plan that is followed in the reading of proofs of engraved topographic maps. (See p. 337.)

## SUPPLEMENTARY DATA

### GENERAL MAPS

#### DEFINITION

General or geographic maps are maps that show the general rather than the detailed character of a region or large tract of country such as State and United States maps. General maps are usually published on small scales, usually represent large areas, and are more commonly published without any representation of relief other than that which may be inferred from the drainage. Some of the general maps issued by the Geological Survey, however, show relief by means of contour lines, shading, or bands of color. The several classes of general maps published are described below and also in the State index circulars. The general maps are compiled in the section of cartography.

#### INTERNATIONAL MAP OF THE WORLD

*Character.*—By international agreement most countries are now engaged in compiling and publishing a sectional world map that is being issued on a uniform scale of 1:1,000,000, or approximately 1 inch to 16 miles, each sheet covering 4 degrees of latitude and 6 degrees of longitude. The maps follow standard international specifications, so that the people of each nation may read and understand the maps of all other nations, regardless of differences in language. The United States maps of this series are in course of preparation and publication by the Geological Survey, and of the 52 sheets that

will cover the entire United States four have been published; these are K 19 (Boston), K 18 (Hudson River), J 10 (San Francisco Bay), and I 10 (Point Conception). An index map of the United States has been issued to show the location of the areas covered by these maps and those to be published, and also the mode of designation by letters and numbers.

*Compilation.*—So much of the base map as has previously been compiled on a scale of 1:500,000 for the State map series (see “Map compilation,” p. 362) and is needed for the international sheet in hand is reduced to a scale of 1:750,000 and printed in light blue on drawing paper to serve as a base for the compilation of the additional features represented on the international series, such as land contours, submerged contours, and highways. The copy for engraving is prepared in the section of cartography.

*Projection.*—For the engraved plates of the sheets of the international map of the world the modified polyconic projection is used, to which the reduced maps of the 1:500,000 scale compilation on the Lambert conformal conic projection are readily fitted in the transfer to copper on a scale of 1:1,000,000.

*Reproduction.*—The United States maps of this series are reproduced by engraving. Each map is printed in several colors and in the symbols determined by international agreement, which differ in some respects from the standard symbols adopted by the Federal Board of Surveys and Maps for Government use. Cities, railroads, State and county boundaries, and names are shown in black; streams in blue; highways in red; land contours (metric) in black;<sup>6</sup> and submerged contours (metric) in blue. The successive heights of the land surface are further emphasized by hypsometric tints ranging from green for the lowlands to pale buff for higher elevations, gradually deepening to a brick-red at snow line, above which the region of perpetual snow is indicated by the absence of color. For the water, beginning at the shore line, a pale-blue tint is employed to represent shallow water; a gradually deepening tone of blue for depths down to 6,000 meters; and the darkest blue for all greater depths.

#### STATE MAPS

*Character.*—Maps of all the States except California (which is partly completed) have been published on a scale of 1:500,000, or approximately 1 inch to 8 miles. The features shown are cities and towns, railroads, State, county, and reservation boundaries, township lines of the public-land surveys, and streams, all with their appropriate nomenclature. The earlier issues were printed in black, but those

<sup>6</sup> The original specifications provided for the printing of land contours (metric) in brown, but the color for this feature was later changed to black.



more recently compiled are printed in two colors, the drainage in blue. The State maps are reproduced by photolithography. Their uniform scale affords opportunity for a direct comparison of size and for the combination of any number of them into a single map on the same scale or reduced by direct photolithography. In addition to their use as general maps, they are extensively used as bases on which to overprint in colors special information, such as geology, the location of oil, gas, and coal fields, power-transmission lines, and national forests.

*Projection.*—In the earlier one-color editions the modified polyconic projection was used, but the present two-color maps are based on the Lambert conformal conic projection, in which the parallels are represented as arcs of concentric circles and the meridians as straight lines. The Lambert projection used for each State map is but a section of one covering the entire United States, so that each map if desired may be fitted exactly to the maps of adjoining States to form a huge map of the country. An added advantage resulting from the use of this projection for the State map series lies in the fact that the slight error in scale is the same in all directions and that the true shapes of the areas represented are retained. Tables for the construction of the Lambert projection are given in Coast and Geodetic Survey Special Publication 52. The construction of the projection is facilitated by the use of a plate recently devised in the section of cartography which obviates the use of beam compass and scale and provides for a mechanical construction of an accurate projection on the scale of 1:500,000 for any area in the United States.

*Compilation.*—State maps are compiled on the scale of publication (1:500,000) and the same base after reduction to a scale of 1:750,000 is used for the compilation of the additional data needed for the international map of the world. The details of map compilation are described on pages 362–366. The compilation for the State maps is made in sections, a State or part of a State or international sheet being used as a unit, as may be most convenient, and the assembly of the separate parts being left to be accomplished in the transfer operations of photolithography. Preliminary State maps of Utah, Nevada, New Mexico, Oklahoma, and Louisiana have been prepared from State maps issued by the General Land Office and do not represent compilations for the international sheets.

#### UNITED STATES MAPS

*Present series.*—Maps of the United States are published in several sizes, ranging from a large wall map in two sheets, on a scale of 1:2,500,000 (approximately 1 inch to 40 miles), measuring 49 by 76 inches, down to a map on a scale of 1:16,000,000 (approximately 1 inch to 290 miles), measuring 8½ by 12 inches. The maps of this



series were compiled on scales slightly larger than the scale of publication and reproduced by engraving. The polyconic projection was used.

*Proposed series.*—Under a plan recently adopted by the Federal Board of Surveys and Maps there will be prepared a new and inter-related series of general United States maps ranging from a large wall map measuring about 4 by 7 feet, to be published on a scale of 1:2,500,000 (approximately 1 inch to 40 miles) to a small outline map measuring about 4 by 7 inches, to be published on a scale of 1:27,000,000 (approximately 1 inch to 425 miles). Under this cooperative plan the Coast and Geodetic Survey was designated to make the projection and plot the coast lines for the wall map and the Geological Survey was designated to compile the interior data, execute the drafting, and publish this map as well as the rest of the series. The wall map has been compiled on a scale of 1:2,000,000 for publication on a scale of 1:2,500,000 and will be a basic source of data from which the features needed for the other maps of the series can be rapidly used by selection and reduction, each map in turn omitting features and details not suitable to its scale. The wall map will be prepared in several plates in order that it may be printed in several colors and also in order that separate printings may be made of selected features apart from others that are not desired.

The maps of the United States of this series will be based on the Albers projection, in which the meridians are straight lines and the parallels are concentric circles. This projection was selected because it presents a minimum error in scale combined with an equal-area representation in a degree not found in other projections.

#### MAP COMPILATION

Special maps for special and general purposes are prepared for other bureaus and departments and for cooperating States, and in their execution special methods of compilation are used as may be found necessary.

*Definition.*—Map compilation involves the making of a new map based on all previous maps or existing map data that can be found representing any part of the region for which the compilation is to be made. Map compilation is distinctly office work and in general has to do with a small-scale map of a region of relatively large extent, as a State, in distinction from a map of a small area, as a quadrangle, which is surveyed in the field and on a relatively large scale.

Map compilation consists in the collection of the available map data for the proposed map, the selection of such of these data as are found to be most suitable for the purpose, the reduction of the selected map material to the scale of the proposed compilation, its adjust-

ment and plotting on the base compilation sheet, and its inking and preparation for reproduction.

*Collection and selection of data.*—The search for existing compilation data should be as thorough as circumstances warrant, because its object is to bring together all known data that can be used in the construction of the new map, and upon the completeness of the search depends much of the value of the compilation in so far as its representation of known facts is concerned. In the collection of available map data search should be made at those Federal bureaus that either make or are most likely to have collected maps in the region for which a map is to be compiled; the files of the map information office of the Federal Board of Surveys and Maps should be examined; inquiries should be addressed to appropriate State departments, such as State geological surveys and offices of State engineers, and to railroad companies, commercial firms, and individuals. As fast as authentic map compilation data are received they should be graphically outlined on an index map for ready reference.

*Scale and projection.*—A map may be reproduced on the scale of compilation, or the drawing may be reduced in scale. If practicable, a compiled map should be drawn on a scale that is slightly larger than the scale of publication in order to derive certain advantages resulting from reduction. The series of State maps compiled by the Geological Survey on a scale of 1:500,000 are based primarily on the needs of the international map of the world, the sheets of which are engraved on the reduced scale of 1:1,000,000. The 1:500,000 State maps are therefore in a sense by-products of the international series. The inking of so much of the 1:500,000 compilations as are included in the State map series must conform to the drafting needs for reproduction on the same scale, whereas so much of the compilation as pertains only to the data that are reproduced by engraving for the international sheets on the reduced scale of 1:1,000,000, such as the contours and highways, may be inked with slightly less exactitude.

The different projections used by the Geological Survey in map compilation are described under "General maps" (p. 359). For other map compilations not listed above the projection used should be the one best suited to the map in hand, the selection being governed by the area to be represented, the scale of the map, and the purpose for which it is intended. The projection should be made to cover the entire area of the proposed compilation but should be drawn in small sections if so warranted by the convenience of office use.

*Control.*—All maps that are to be used in a compilation must be reduced to the same horizontal datum, for which the North American

datum is standard. If the data used are fully controlled, as in the Geological Survey quadrangle maps and Coast and Geodetic Survey charts, no further control is needed. Such maps and charts should be corrected to the North American datum if necessary and when reduced to the scale of compilation may be transferred directly to the projection. Before compiling those parts of the map that are not covered by maps resulting from controlled surveys, all available triangulation and transit-traverse positions that fall within the area of the map should be plotted so far as they can be used in adjustments. To the primary control thus established data from railroad, river, and other instrumental surveys are tied in an effort to subdivide the map with lines of supplemental control and into small sectors, in order that the use of the additional data of a miscellaneous nature may require only local adjustment. For maps within the public-land States the entire network of township lines should be adjusted and plotted from the records of the General Land Office, and inasmuch as this compilation may be regarded as preliminary and subject to change before the final adjustment is determined, it is generally convenient to make it on tracing paper on which the projection and control have been traced and later to transfer it into position on the map.

*Reduction.*—Before any map data (other than initial control) can be transferred to the map they must be reduced or, if necessary, enlarged to the scale of the compilation. The reduction may be effected by photography, but it is more practicable to use the pantograph, because with that instrument only the features desired need be included and the copy can be made on thin tracing paper, which facilitates the adjustment and transfer of the data to the map. If a pantograph is used a clearer impression can be obtained if carbon paper is placed over the tracing paper and a metal point is used in the pantograph instead of a pencil point. Carbon paper of different colors may be used to obtain any desired distinctions, such as blue for drainage lines. It will generally be more convenient to reduce large-scale township plats by sketching the data on blocks of sectionized townships that have been made on the scale of the compilation and printed on transparent paper, as data thus prepared can be readily transferred to the map.

*Adjustment and transferring.*—The most authentic maps should be first incorporated in the compilation, as their plotting will afford further control to which maps that have been less completely controlled can be tied, and thus through a gradual building up process, often through repeated trial adjustments of the less reliable data, the final adjustment and compilation are accomplished. A map, even though well drafted, should be fully tested before it is used, and a map should not be discarded because it lacks in appearance



only. Although the suitability of existing maps or map data can in general be determined by inspection, the ultimate determination may rest upon the possibility of fitting or reconciling them to other data covering the same or adjacent territory.

Although a large part of the generalization of features is accomplished in the pantographing, further elimination, especially in drainage, may be needed when the data are transferred. Features such as railroads do not need so much generalization, and boundary lines should be delineated as accurately as the scale will permit.

*Inking.*—The process of reproduction determines the method of inking. If the map is to be engraved all the features are included in one drawing, but great refinement in the drafting is unnecessary. The photolithographic process requires excellent drafting, and if the map is to be printed in more than one color a separate drawing may be made for each of the colors used if desired. The most satisfactory method of doing this is to provide photolithographic copies of the pencil compilation, one for each color to be used, printed in nonphotographic blue on drawing paper or bristol board. Only the features that are to be printed in the same color are included in one drawing, and as the blue copies of the map are identical, perfect register should be assured when the reproductions of the several drawings are combined in the printed map. The drainage should be carefully generalized as it is inked, and as a rule streams less than 6 miles in length may be omitted in a compilation on a scale of 1:500,000. Main streams should be inked heavier than the small tributaries, and a distinction should be made between perennial and intermittent streams. State and county boundary lines should be drawn reasonably bold, but public-land lines, with the exception of base lines and principal meridians should be inconspicuous. Railroad tracks should be represented by firm lines, with very short lines for the cross ties, which should be spaced at intervals of not less than one-tenth of an inch.

*Lettering.*—In planning the lettering for the map, a complete diagram in which provision is made for the position each name is to occupy should be prepared for the draftsman's use. The diagram may be made in pencil on a photograph or photolithograph of the compilation. The map should not be congested with names, and in the selection of a place to be named consideration should be given to its population, importance as a railroad or postal center, and commercial or historical importance. In thickly settled regions the names of many places of only local importance must be omitted for lack of space, but in sparsely settled areas the names of small settlements or even of ranch houses assume importance as reference points. Space may be economized, where necessary, by abbreviating railroad names and by using "R" or "Cr" for the words "River" and



"Creek." All place names should be lettered in a horizontal position, and the names of railroads and streams should follow their meanderings and be so placed as to read from the south edge of the map. The spellings approved by the United States Geographic Board must be followed, and the diagram should be carefully checked before the lettering is executed. The lettering may be done either by hand, by means of pasting type impressions on the map, or by a combination of both. Single-stroke lettering is comparatively easy to do and reproduces well, and its use is recommended. If type impressions are used instead of hand lettering the names should be listed in systematic order for type setting and printed on light-weight gummed paper. In applying names printed from type they should be cut out without much margin and pasted on the map, care being taken to avoid as much as possible, covering up any of the features. It is more satisfactory to letter the stream names by hand, and this should be done on the drainage drawing, in the event that the colors of the map are separated in the drafting.

*Checking.*—During the whole course of the compilation the map should be constantly verified, so that upon its completion it may be free from error. It should also, however, be subjected to a final exhaustive checking, and such errors as are then detected should be corrected before it is sent to the printer.

*Compilation record.*—As the compilation progresses a record should be kept of the data that were used, and this record should be later transcribed to a printed copy of the map. Errors or omissions that may be detected from time to time should be noted on a file copy of the map, for correction in the next edition.

*Reproduction.*—Compiled maps are generally reproduced by photolithography, although engraving is used for such maps as those of the United States and of the international world series. To assist the lithographer in retaining the scale of a map reproduced by photolithography a projection should be constructed on paper mounted on a metal plate to serve as a key sheet in assembling the map for transfer to the printing stone.

#### SHADED RELIEF MAPS

Relief may be represented on maps by means of contour lines, form lines, hachures, or shading. It may be expressed by shading alone, or the shading may supplement other means of expression, as contouring. If relief shading is artistically added to the contouring it will so tend to throw into the background the rigid details of contour construction and so emphasize the broader features of the map as to give to the map a relief expression that may be understood by laymen unfamiliar with contour lines. Shaded relief maps may also assist map users who, although versed in the theory of contours,

can not in practice get a picture of a region from a glance at a contour map of it; and the trained map user may often see in the shaded map some general aspect of the terrain that he has failed to grasp in the exacting detail of the contouring. Finally, even the engineer or geologist may find in relief shading, especially when a number of such maps are used in combination, a meaning to be recognized in no other way save through models. As relief shading is a generalized portrayal of the relief in a pictorial sense, data of insufficient accuracy for contouring may often be employed with pleasing and advantageous effect.

In the early years of the Geological Survey experimental work in relief shading was carried on with some success, two such maps being published about 1882 by the lithographic process, but owing to the prohibitive cost of reproduction at that time the plan was abandoned. In recent years the discovery of the cheaper and more effective photo-transfer process has afforded a means for economical publication and caused a revival of interest in relief shading, which has grown in popularity and developed to such an extent as to enlist the commendation of geographers throughout the world.

Although shaded relief maps are called picture maps, they in reality portray with remarkable fidelity all the bolder topographic features, both in precise location and physical character, the illusion of relief being obtained by a judicious manipulation on the drawing of lights and shades so as to produce an effect similar to that which would be obtained if a carefully sculptured relief model were obliquely illuminated by the sun around 4 o'clock in the afternoon of a day in late summer. In addition to the representation of the bolder forms of relief, relative differences in elevation of valleys, plateaus, and other lesser relief forms are shown by a system of delicately graded tints—dark tints for the lowlands, grading upward to light tints for the highlands. This mode of representing high and low lands has been developed in the Geological Survey and differs from other forms of hypsographic expression. Shaded relief maps should not be confused with those in which the process of modeling in clay or other plastic material has been used.

The Geological Survey has published a general shaded relief map of the United States on a scale of 1 : 3,168,000, one of Alaska on a scale of 1 : 2,500,000, and shaded relief State maps of Ohio (1 : 380,160), Arizona (1 : 500,000), Kentucky (1 : 500,000), and Idaho (1 : 760,320) and has in preparation similar maps of Pennsylvania, New York, New England, West Virginia, New Mexico, Colorado, and Wyoming. Shaded relief editions of 12 recent topographic maps have also been published, in which the shading has been overprinted in a light olive-drab over the contours; for these editions special printings of the topographic base are made in colors that harmonize

with the overprinted relief shading. The methods of relief shading are also used for illustrations that show in detail special types of physiographic phenomena and geologic structure.

In the compilation of a base map upon which to add relief shading for maps of areas for which no contour maps are available, all authorities bearing upon the probable relief are used, including interviews with those who have traveled through any of the unmapped regions. Thus, in the preparation of the manuscript for the shading of the wall map of the United States over 5,000 maps were used, and many persons who had personal knowledge of unsurveyed areas were interviewed.

### UNITED STATES SYSTEM OF PUBLIC-LAND SURVEYS

The following discussion, based on the "United States manual of public-land surveys," to which the topographer is referred for more detailed information, is intended to give a general outline of the plan and practices of the public-land surveys.

#### TOWNSHIP UNITS

The unit of the system is the township, a tract 6 miles square, or nearly so, bounded on the east and west by true north-south lines, and on the south and north by east-west lines, and subdivided into 36 sections, each a mile square, or nearly so.

As true north-south lines (that is, meridians) converge northward to the pole, it is evident that the width of a township decreases slightly from south to north (41.9 links in latitude  $30^{\circ}$  N. to 86.5 links in latitude  $50^{\circ}$  N.),<sup>7</sup> and that its shape is really trapezoidal and not square. It is evident also that as the meridian lines are extended northward townships will become progressively narrower and will be reduced in area. These complexities growing out of the inherent convergence of meridians on a spherical surface like that of the earth were not taken into account in framing the original law, the intent of which was apparently to provide for square units of uniform size; nor was any provision made for a system of control lines whereby the narrowing of the townships, on the one hand, and the inaccuracies in the surveying of the subordinate lines, on the other hand, might be kept within convenient limits. However, the first public-land surveys to be executed, notably the classic "Seven Ranges" in Ohio, demonstrated the need of remedying these defects, and as a result there has been evolved by successive legal steps a system of rectangular surveying which "harmonizes the incompatibilities of the requirements of law and practice" and has become the accepted standard for the entire country.

<sup>7</sup> All public-land measurements are expressed in chains and links. A chain of 100 links is equivalent to 66 feet common measure, and 80 chains equal 1 mile.



## PRINCIPAL MERIDIANS AND BASE LINES

All surveys in a given area are referred to two primary lines, a principal meridian and a base line, passing through an initial point; the one is a true north-south line and the other a true east-west line—that is, a parallel of latitude. These two lines constitute the axes of the system, and the township units are numbered with reference to them in consecutive tiers to the north and to the south, beginning at the base line, and in consecutive ranges to the east and to the west, beginning at the principal meridian. Any township, accordingly, may be designated by tier and range number, as T. 14 N., R. 7 W. fourth principal meridian, or T. 10 N., R. 28 E. Mount Diablo principal meridian. The principal meridian must be added to each designation to give complete identification; there are about 30 separate systems in the United States, each with a separate set of axes and a separate system of numbers. The number or name of the principal meridian serves to distinguish these from one another.

## STANDARD PARALLELS AND GUIDE MERIDIANS

From the principal meridian, commonly at intervals of 24 miles, auxiliary base lines called standard parallels, or correction lines, are extended east and west. They are numbered each way from the base line—for example, first standard parallel north, third standard parallel south.

From the base line, usually at intervals of 24 miles, auxiliary meridians called guide meridians are run due north. They are numbered each way from the principal meridian—for example, first guide meridian east, second guide meridian west. As they converge appreciably in a distance of 24 miles (the exact amount depending on the latitude), they are not continued beyond the first standard parallel north but end at closing corners on that line and start afresh from standard corners a full 24 miles apart. It will therefore be seen that standard parallels have two sets of corners, one set referring to lines north of the parallel and the other being established by township and section lines from the south, closing on the parallel. The process is repeated at the second and each succeeding standard parallel. Each guide meridian thus runs due north from parallel to parallel, and on each of the parallels is an offset to correct for convergence.

South of the base line guide meridians are run not south but north, so that the blocks inclosed between them and the parallels are essentially similar to those north of the base line. In case conditions require that a guide meridian be run south it must be begun at a properly computed and established closing corner.

The standard distance of 24 miles between parallels and meridians is not always strictly adhered to. Thus, in many parts of the far



West there are five tiers of townships (30 miles) between parallels and six, seven, or more ranges between guide meridians. In some places these irregularities in the spacing of the standard lines necessitate the introduction of intermediate meridians and parallels. These are designated by local names.

The offsets of the meridians on the parallels and their closing distances are of special importance in the plotting of guide meridians and standard parallels, and these data the topographer should not fail to procure from the General Land Office.

The meridional convergence increases proportionately to the distance from the principal meridian. Therefore the offset of the second guide meridian is double that of the first guide meridian (between the same parallels); that of the third guide meridian is three times as great; and so on in proportion (the intervals being assumed to be regular). Again, the convergence increases slightly northward with the latitude. Thus the offset of a first guide meridian in latitude  $50^{\circ}$  is more than double what it would be in latitude  $30^{\circ}$ . Of course the actual offsets depart somewhat from the theoretical offsets because of inaccuracies in surveying, and this makes it all the more imperative that they be noted on the plats.

It is to be remembered that all errors of closure in distance are thrown in the last mile and are not distributed over the entire length of the line. The spacing of the corners along the line is thus not affected by the amount of the closure.

#### TOWNSHIP EXTERIORS

Whenever practicable the survey of township exteriors within a block bounded by standard lines begins with the southwest township and continues northward until the entire west range is completed; thence it goes from south to north through the next range east, etc. The mode of procedure is first to run the east boundary of a township due north a full 6 miles; then to run its north boundary on a random or trial line from east to west, correcting back on a true line after the "falling" north or south of the northwest township corner has been ascertained. The closure in distance, however, is thrown in the last half mile at the west end of the line—that is, between the last quarter-section corner and the township corner. The purpose of this is to throw the meridional convergence and all irregularities arising from inaccurate surveying toward the west boundary of the township. The last quarter-section corner accordingly lies not midway in the last mile but always an even 40 chains from the mile corner east of it, whatever the distance between it and the township corner may be.

In getting data for platting township exteriors, therefore, special note should be made of the closing distances at the west ends of the latitudinal township boundaries. The accuracy of the surveys may

be gaged from a comparison of the actual with the theoretical closing distances as indicated below:

*Theoretical closing distances at different latitudes*

Latitude	Closing distance	
	Chains	Feet
30°	79.58	5,252
35°	79.49	5,246
40°	79.39	5,240
45°	79.27	5,232
50°	79.14	5,223

In the northermost tier of townships in a block it is further necessary to take note of the closing distances of the range lines on the standard parallel. Theoretically these distances should be an even 80 chains, but inaccuracies in the azimuth of the standard lines on the one hand and of the township lines on the other hand usually cause discrepancies. It frequently happens that the length of chain used for the one set of lines differs appreciably from that used for the other, and the closure errors may then amount to several chains. Such discrepancies should be marked on the plats.

#### SECTION LINES

Each township is divided by section lines into 36 sections, which are numbered consecutively, commencing with No. 1 at the north-east corner of the township and proceeding west to No. 6, thence east to No. 12, thence west to No. 18, and so on, alternately east and west, to No. 36 in the southeast corner. In all fractional townships the sections bear the same numbers they would have if the township were full.

As townships are trapezoidal and not square, they do not contain a full 36 square miles each but fall short of that amount by a number of acres. It being undesirable to distribute this shortage among all the 36 sections, the law provides that it shall be thrown into the westernmost range of sections, and that the other sections shall be laid out so as to contain a full 640 acres each, as near as may be. Accordingly, the longitudinal lines between sections are run not due north but parallel to the east boundary of the township. Each bears slightly west of north, according to the latitude of the township and its distance from the east boundary. The latitudinal section lines are run parallel to the south boundary of the township—that is, as a rule they run practically east and west.

The subdividing of all normal townships begins with the south-east section. Its west boundary is run N. 0° 1' W. a full 80 chains; its north boundary is then run east on a random or trial line, a quar-

ter-section corner being temporarily placed at 40 chains. The "falling" north or south from the appropriate corner on the township boundary having been measured, the quarter-section corner is then shifted proportionately and set exactly midway between the section corners. In many of the older contracts these rules were not faithfully carried out, and in consequence little dependence is to be placed on the position of the quarter-section corners on the latitudinal section lines. The west boundary of the next section north is then run out, and then its north boundary as before, and so on through the entire east range of sections. The other ranges are taken up consecutively from east to west, each being surveyed from south to north. The range lines of the northernmost tier differ from the others in that they are connected with the corners along the township boundary and consequently are not always parallel to the east boundary nor measure an even 80 chains in length. Theoretically they should do so, but in practice the inaccuracies in the surveying of the township exteriors, on the one hand, and of the section lines, on the other hand, cause discrepancies. Accordingly, these lines are run first on a random or trial line parallel to the east boundary and then corrected back according to their falling. In order to confine the irregularities in acreage to the northernmost tier of lots, the excess or deficiency in measurement is thrown north of the quarter-section corner, which is consequently set not midway but an even 40 chains from the south end of the line.

In the west range of sections, again, the latitudinal lines are connected to corners along the west township boundary. Each is therefore run first on a random parallel to the south boundary of the section and then corrected back according to its falling. Here again, in order to confine the irregularities in acreage to the westernmost range of lots, the error (which normally is a deficiency equal to the meridional convergence) is thrown west of the quarter-section corner, which is consequently set not midway but an even 40 chains from the east end of the line.

#### MEANDERS

Where any lines cross rivers the right-angle width of which is 3 chains or more, lakes, bayous, and deep ponds having an area of 25 acres or more, meander corners are established on each bank, and from these are run meanders (corresponding to traverse lines) along the banks, to close on other meander corners. Similarly, water bodies having an area of 25 acres or more, lying within sections, are surrounded by a meander tied to the two nearest section or quarter-section corners. Islands are located by triangulation from meanders on the shore, an auxiliary meander corner being established on each one of them.

Meanders are run for the sole purpose of providing a definite boundary for the land areas in the lots abutting on water bodies, so that the acreage of such fractional lots may be computed with accuracy. There is consequently no object in publishing meanders on the topographic maps, and they are to be omitted. At the same time, distances to meander corners and notes or plats of meander lines are often of great value in the construction of the maps in the field, and such data should therefore be procured.

Care should be taken in drafting the field sheets to discontinue land lines at such river banks and lake shores as have been meandered. They should not be represented as crossing the water body unless the lines were actually so run.

#### BLAZING LINES

Trees on a line have two chops or notches cut on the side facing the line. Other trees standing within 50 links of the line, on either side of it, may be blazed on two sides diagonally or quartering toward the line, the blazes approaching nearer each other the farther the tree stands from the line.

Random lines are not blazed.

#### MARKING CORNERS

*Classes.*—Land-survey corners are divided into the fourteen following classes, each of which has a distinctive set of marks and is marked in accordance with definite rules:

Standard township corners.

Closing township corners.

Corners common to four townships.

Corners common to two townships only.

Corners referring to one township only.

Standard section corners.

Closing section corners.

Corners common to four sections.

Corners common to two sections only.

Corners referring to one section only.

Quarter-section corners.

Standard quarter-section corners.

Meander corners.

Corners on reservation or other boundaries not conforming to regular system.

Each of these fourteen classes of corners may be constructed as the character of the country and the availability of the materials permit, in eight different ways as follows:

Stone, with pits and mounds of earth.

Stone, with mound of stone.

Stone, with bearing trees.



- Post, with pits and mounds of earth.
- Post, with bearing trees.
- Mound of earth, with deposit and stake pit.
- Tree corner, with pits and mound of earth.
- Tree corner, with bearing trees.

No less than 112 different combinations may be met in the field. There is, however, no need of describing each combination separately; the marks follow a definite simple system and in a measure are self-explanatory.

*Notches and grooves.*—Stones and posts on all township and section corners (except those on standard parallels) are set diagonally to the lines—that is, with an edge on each line. On the edges are cut notches, the number of which indicates the number of miles to the nearest township corner in the direction of the edge. Thus, the first mile corner on a range line between two townships has one notch on the south edge and five notches on the north edge; and the second mile corner has two notches on the south edge and four notches on the north edge. On a latitudinal township boundary the first mile corner west of the township corner has one notch on the east edge and five notches on the west edge; and the second corner west has two notches on the east edge and four notches on the west edge. A corner common to four townships has six notches on each of its four edges.

Section corners within a township are notched on their south and east edges only. The number of notches on them therefore indicates the distance in miles to the south and east township exteriors, respectively. Thus, the corner between secs. 25, 26, 35, and 36 has one notch on its south edge and one notch on its east edge; the corner between secs. 10, 11, 14, and 15 has four notches on its south edge and two notches on its east edge; the corner between secs. 5, 6, 7, and 8 has five notches on both its south and east edges.

Stones and posts on standard parallels are set square with the lines—that is, with a flat face on each line. Their faces are grooved, the number of grooves on any face indicating the number of miles to the nearest township corner in the direction of the face. Accordingly, standard township corners have six grooves on their north, east, and west faces; closing township corners have six grooves on their south, east, and west faces. Standard section corners are grooved only on their east and west faces with respect to the standard township corners. Closing section corners are similarly marked with respect to the closing township corners.

Tree corners are notched to correspond with the notches or grooves which stones or posts would bear in the same situation.

*Additional marks.*—Standard corners of all kinds are marked "s c" on the north face; closing corners, "c c" on the south face. If posts or trees are used the township and range numbers also are indicated

on the appropriate sides of standard and closing township corners, and the township, range, and section numbers on the appropriate sides of standard and closing section corners.

Posts at ordinary township corners have each township and range marked on the appropriate face; tree corners bear the same marks on large blazes.

Posts at section corners are similarly marked with the numbers of the surrounding sections and, in addition, with the number of the township and range on the northwest and northeast faces, respectively.

Quarter-section corners are marked " $\frac{1}{4}s$ " on their north face if on a latitudinal line, on their west face if on a meridional line. If stones are used the "s" is omitted.

*Pits and mounds.*—In open country where the soil is soft enough to permit digging square pits are dug about each corner, and the earth taken from them is heaped up into a conical mound. At corners common to four townships the mound is placed immediately south of the monument; at corners common to four sections, west of the monument; at standard corners, north of the monument; at closing corners, south of the monument; and at quarter-section corners, north or west of the monument, according as the line is latitudinal or meridional.

The pits are placed on each line about all corners except section corners; at these the pits are placed diagonally, one in each section.

Where neither stone nor wood is available for suitable corner monuments a marked stone, charred stake, or quart of charcoal is deposited 1 foot below the surface of the ground and the mound placed above it.

Where the ground is stony and does not permit the digging of pits, a pyramid of stones is built in lieu of a mound.

*Bearing trees.*—Bearing trees, each with a large blaze facing the corner monument, are used wherever the required number of trees within proper distance is available. They are disposed and marked as follows:

At township corners, one in each surveyed township, marked with township, range, and section number, followed by the letters "B T" (bearing tree). At section corners, one in each section, marked with township, range, and section number. At standard corners of all kinds, two trees, one in each section north of the parallel; at closing corners, two trees, one in each section south of the parallel. At quarter-section corners, two trees, one in each section.

*Witness corners.*—When the true point for any corner falls in a place where its destruction by natural or other causes would be certain, a witness corner is established in a secure position on a surveyed line, if possible, within 20 chains of the corner point, thus witnessed.

A witness corner bears the same marks that would be placed on the corner for which it is a witness with the addition of the letters "w c" conspicuously displayed above the markings. Its bearing trees, similarly, are marked "w c."

#### ADJUSTMENT OF PUBLIC-LAND LINES

To adjust the lines of the public-land surveys to the control of a topographic map it is necessary to understand the manner in which those lines were run. (See preceding section.) This adjustment offers a direct parallel to the relocation of lost land corners of the public-land surveys in the field. For purposes of adjustment the land corners located by the control are the only known corners, and all other corners, to be located by adjustment, must be considered lost corners. The approved methods for the relocation of lost corners of the public-land surveys have been developed to conform to court decisions as to what constitutes the most reasonable location for such corners. Apparently the topographer can do no better than to follow the rules for the relocation of lost corners in his adjustment of the lines of the public-land surveys to his field sheet.

On principal meridians, guide meridians, base lines, standard parallels, and township and range lines, the lost corner should be restored in line between the nearest known corners on the same line and at distances from them proportional to those shown in the field notes and on the plats of the original survey. This rule assumes that the original line was a straight line. Frequently it is not, but in most places the variations from a straight line are first in one direction and then in the other, approximating a straight line so closely as to be difficult to show otherwise on the scale of a topographic map. In the absence of definite knowledge to the contrary, it is best to assume that the original line was straight.

Lost township corners that are common to four townships should be restored at distances from the nearest known corners, north, south, east, and west, proportional to those shown in the field notes and on the plats of the original survey. This rule also applies to the relocation of lost interior section corners. Lost township corners that are common to only two townships should be restored in line between the nearest known corners on the same line and at distances from them proportional to those shown in the field notes and on the plats of the original survey.

Lost quarter-section corners should be restored in line between section corners that stand on the same line at distances between them proportional to those recorded in field notes of the original survey. Quarter corners for which such distances are not given on the plats are midway between and on line with adjacent section corners.

Distances along township and section lines that are not given on the land plats are an even 80 chains. The distance is given for the last quarter of the last mile to the west and to the north in each township, as any discrepancy is thrown into this quarter, other fractions of the mile being 40 and 20 chains unless otherwise shown.

The rules given above will not apply rigidly and inflexibly to all cases. The best judgment of the topographer should always be applied to find out or decide not where the corner or line ought to have been but where it actually was. In exercising such judgment the topographer may have to wait until he can supplement his control with traverse lines before he can adjust the land net with accurate results.

In applying the above rules to the adjustment of the land net to his field sheet, the topographer should first sum the distances as given by the plats along the township exteriors across his sheet from control point to control point, both in a north-south and an east-west direction. The same distances between control points should be carefully scaled from the field sheet. In summing the distances from the plats it is best to take the distances as given on the north side of the east-west lines and on the west side of the north-south lines, as there will be fewer fractional distances and the sum will be the same as if distances given on the other sides of the lines had been taken. Any discrepancies between the summed and the scaled distance for any line should be distributed proportionally to distances given by the plats, and the east-west and north-south location of each township corner should be marked on the field sheet by a short line at right angles to the direction in which the line is measured. The intersection of these short lines or dashes, drawn at right angles to each other, gives the adjusted location of the township corner. In the absence of definite information to the contrary, it is most reasonable to assume that straight lines connecting the corners with adjoining corners of the same line and with control locations on township exteriors will give the adjusted location of the township exteriors. After the exteriors have been drawn the section corners on the north side of the east-west lines and on the west side of the north-south lines should be plotted, the same proportional correction to the distances shown on the plats being made as was applied for the same line in the location of the township corners. Corners on the opposite sides of the same lines should be plotted next, the offset distances shown on the plats being used and the same proportional corrections being applied if the distances are large enough to warrant it.

The corners along the township exteriors located by adjustment can now be used as found corners for the adjustment of the interior section corners of the several townships. This work should be done in the same manner as the location of the township corners. Dis-



tances along section lines across the township both in a north-south and an east-west direction should be summed from the plats and scaled from the field sheet. Any discrepancy between the two should be distributed to the sections in proportion to their distances as shown on the plat, and a north-south and an east-west location should be marked for each section corner by a short line at right angles to the direction in which the measurements were made. The intersection of these short lines gives the adjusted location of the section corners. Lines joining such points in the same lines give the adjusted locations of the section lines.

By the method of adjustment above set forth errors in the original surveys due to the use of a chain that was too long or too short are taken care of, and bends in the section lines at section corners are faithfully reproduced on the field sheet. Gross errors or fraudulent work in the original surveys can not be taken care of by any method of adjustment. They are, by the method here prescribed, confined to the township in which they occur.

In localities where the public-land surveys are known to be poor or where discrepancies between the plotted and the scaled distances are so large as to indicate a weakness in the land surveys, it is best to wait until the control can be supplemented by stadia traverse or by other means before attempting to adjust the land net to the field sheet. This precaution is equally desirable if the marginal control is weak or the topographer has to depend on railroad control.

When the township and section lines are well adjusted, the quarter and the sixteenth section lines can be drawn on the field sheet as an aid to the topographer in future work.

# F. MAP COMPILATION FROM AERIAL PHOTOGRAPHS

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By T. P. PENDLETON

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## INTRODUCTION

The value of photographs for map construction was appreciated immediately after the invention of the camera, and many methods of utilizing photographs made from ground stations for this purpose have been perfected, but until some time after the development of the airplane no attempt was made to use aerial photographs in this way. No effort is made to describe here any of these older instruments or processes, nor methods of compilation other than those used by the Geological Survey.

As considerable experimentation on the design of instruments and the development of a compilation process that will utilize advantageously aerial photographs for mapping has been carried on, it seems advisable to describe the instruments and methods now in use by the Geological Survey, recognizing the fact that they may soon be supplanted by newer and better ones.

## INSTRUMENTS

### SINGLE-LENS CAMERA

The single-lens camera most commonly used is shown in Plate 24 in a dummy installation and is often called the "K" type, the several models being denoted by numbers as "K-3." This camera is entirely automatic and is so designed that the interval between exposures may be varied from 4 seconds to over 1 minute. It is equipped with an anastigmat lens having a maximum stop opening of  $f/4.5$  and a focal length of 12 inches. The shutter is of the "between the lens" type and gives exposures of  $1/50$ ,  $1/100$ , and  $1/150$  second. Photographs 18 by 24 centimeters are made on roll film about 75 feet in length, sufficient for about 120 exposures. The camera is motor driven, power being provided by a storage battery, and may be loaded during flight, as the magazine with the exposed film may be removed and another containing unexposed film quickly substituted.

The intervalometer controlling the intervals between exposures having been set to give the desired overlap of photographs, the motor will trip the shutter, count the exposure, remove the pressure of the film-pressure plate, wind an unexposed portion of the film into position, replace the film-pressure plate so that the film is held in close contact with the glass focal-plane plate, and set the shutter ready for the next exposure. The camera is suspended in gimbals that allow it to be rotated about its vertical axis and to be leveled in the focal plane. A horizontal position of the focal plane is indicated by a circular level attached to the camera.

#### RECORDING CONE

The latest model of the single-lens camera is the K-8 type. This camera is in certain minor details simply an improvement on earlier models, but the recording cone used with it is unlike anything that has been introduced heretofore.

The purpose of this recording cone is to register photographically on the negative, at the moment of exposure, all pertinent data concerning it and thus provide positive identification for each photograph. This is accomplished by photographing on the edge of the negative a watch face, a circular spot level, an altimeter, a mechanical counter, and a card on which any data concerning the flight may be written. This device is set in a door in the side of the lens cone and functions just after the camera exposure has been made and before the film is wound forward. The photograph of the recording device is easily read, although it occupies a space but 10 by 38 millimeters, and as it appears along one edge of the print it does not interfere with the usefulness of the print in the least.

#### MULTIPLE-LENS CAMERA

Multiple-lens cameras of the type so extensively employed at present in the photographic mapping of this country have many advantages due to the large area photographed at each exposure. These advantages are so great that they more than offset the slight indistinctness often encountered at the outer edges of the photographs. This lack of definition does not result from lack of perfection in the construction of the camera, but is caused by the distance and angle at which the objects in this portion of the field are viewed and by the transformation that these oblique views must undergo in preparing them for use in mapping. During the last few years there has been a remarkable improvement in the quality of photographs of this type and it is not too much to expect that this improvement will continue until they are entirely satisfactory.

The multiple-lens cameras are constructed with either three or four lenses each. The four-lens or T-2 camera is an improvement on the tri-lens or T-1 and will probably soon supersede it on account of the increased ease and accuracy of map compilation that it makes possible.

The four-lens camera consists of four sections, two of which are film magazines containing the rolls of film and two contain the lenses and dark chambers of the camera proper. This instrument can be considered a tri-lens camera to which has been fitted an additional, detachable lens unit.

The object in designing the multiple-lens camera was to include a larger field of view at right angles to the direction of flight of the airplane than is given by any photographic lens of large light-gathering power. This was accomplished by fixing the central lens with its axis in the vertical position while the axes of the other two lenses were in the same plane but at an angle of  $35^\circ$  to the left and right. The combined field of view in the plane of the lens axes is  $115^\circ$ , which leaves a liberal margin of overlap of fields for matching the photographic prints. This overlap can be most clearly visualized by considering the two oblique lenses as located in the same position as the central lens, as shown in Figure 13, an assumption which is permissible, as the actual separation is only a few inches. The maximum angular field of view and the amount of overlap differ slightly in different cameras, owing to the small differences that exist in the focal lengths of the lenses selected for each camera.

Front and rear views of the T-2 camera are shown in Plate 25. In the front view the line of division of the upper and lower portions of the camera can be easily distinguished. The base contains three lenses, dark chambers, and focal-plane surfaces. The three lenses and their corresponding focal planes are distinguished by the letters A, B, and C. The compartment for the fourth lens is accordingly called the D compartment. The A, C, and D focal planes make an angle of  $35^\circ$  with the focal plane of the B compartment. A view of the focal planes is shown in Plate 26, A. The center (B) compartment contains two level vials, so placed that an image of the bubbles will photograph on the negative when the exposure is made. The four index marks that appear at the edges of each focal plane play a very important part in the use of the photographs. The intersection of the lines defined by these indexes is the "principal point" of the negative and marks the intersection of the optical axis of the lens with the focal plane.

Rollers are provided at each end and between the focal planes to reduce the friction encountered in winding the film into position. The lenses have a focal length of about 7.5 inches for the A, C, and



D chambers and are matched at the factory to about 0.10 millimeter in order to insure equality of focal lengths. This agreement of the focal lengths of the oblique lenses renders the transformation of the negatives a relatively simple matter. The B compartment is equipped with a lens having a focal length of about 6.5 inches, as this shorter focal length permits the construction of a much smaller camera than would otherwise be possible. The lenses have a maxi-

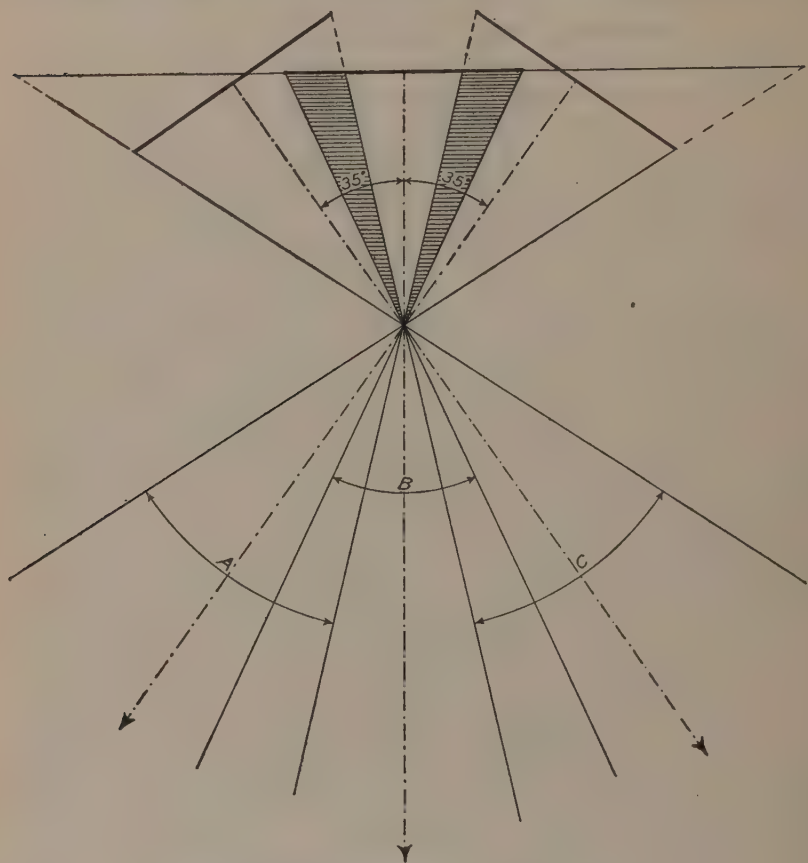
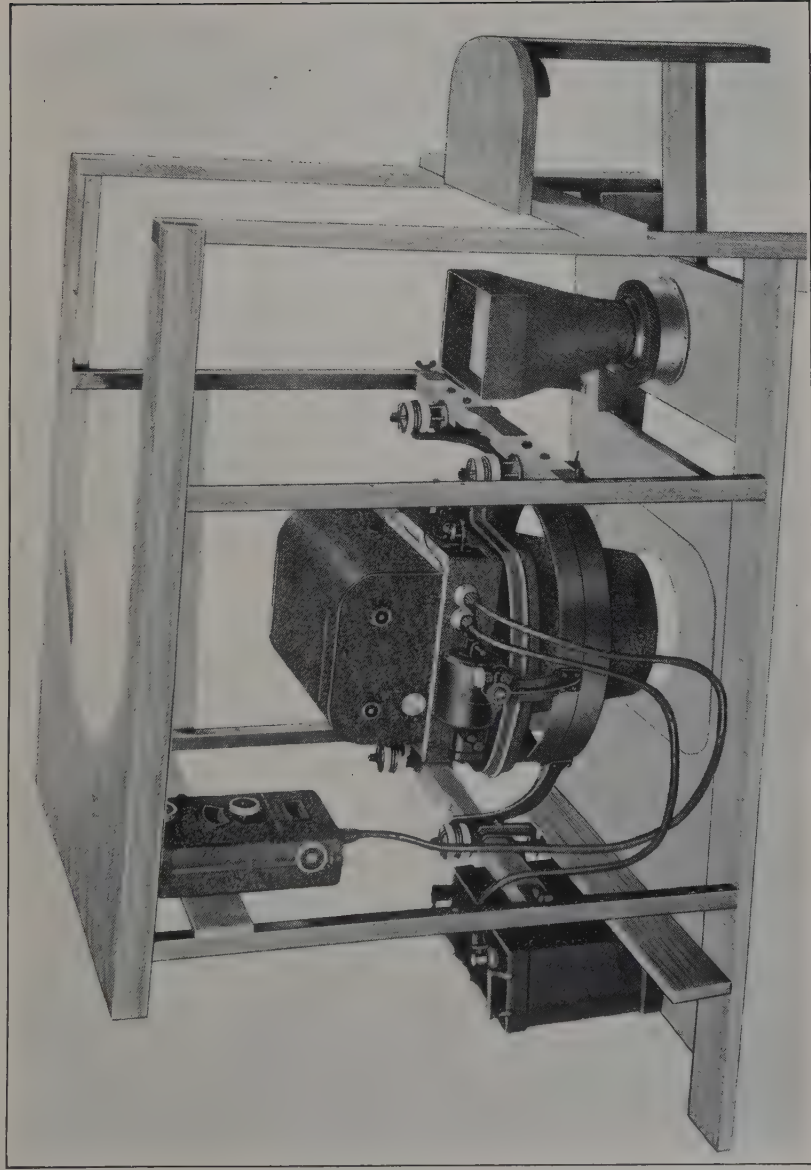


FIGURE 13.—Lateral field of view of T-1 camera.

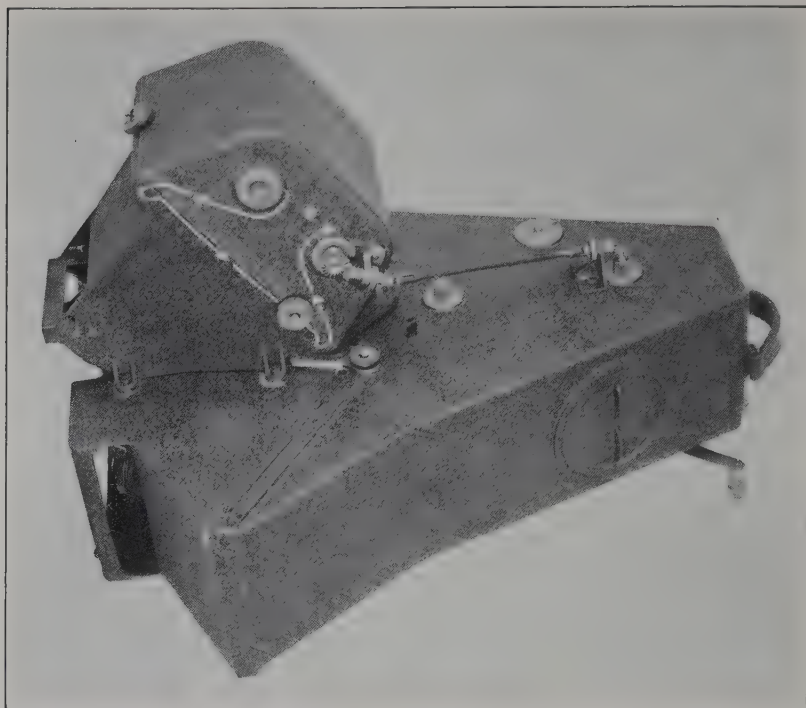
imum stop opening of  $f/4.5$  and are mounted in "between the lens" shutters. The arrangement of the lenses and the shutter-release mechanism are shown in Plate 26, *B*. As it is essential that the four lenses be exposed at the same instant, provision is made whereby the shutters of the oblique lenses can be synchronized with the shutter of the central lens.

The upper or magazine section of the camera can be detached from the base by loosening four clamp screws, two of which are

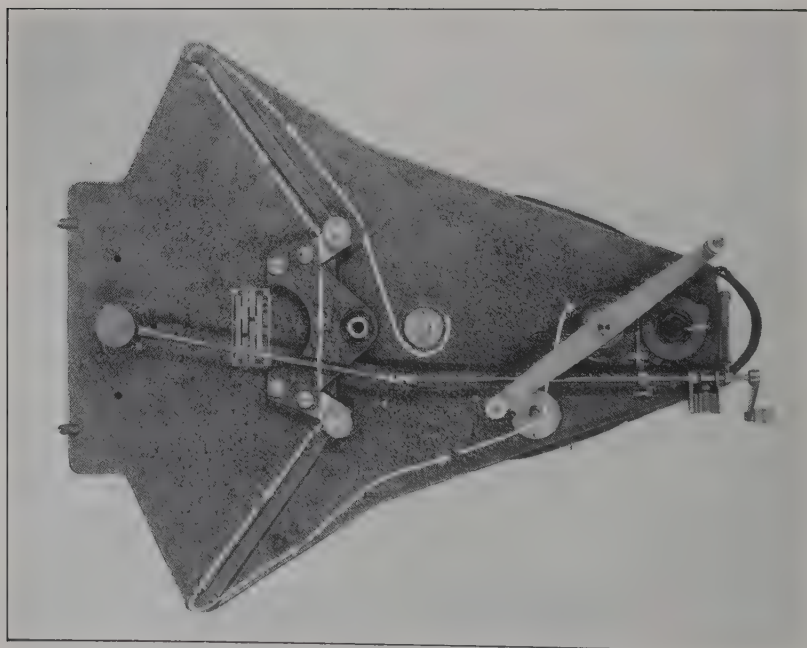


A SINGLE-LENS CAMERA

Photograph used by permission of Fairchild Aerial Camera Corporation



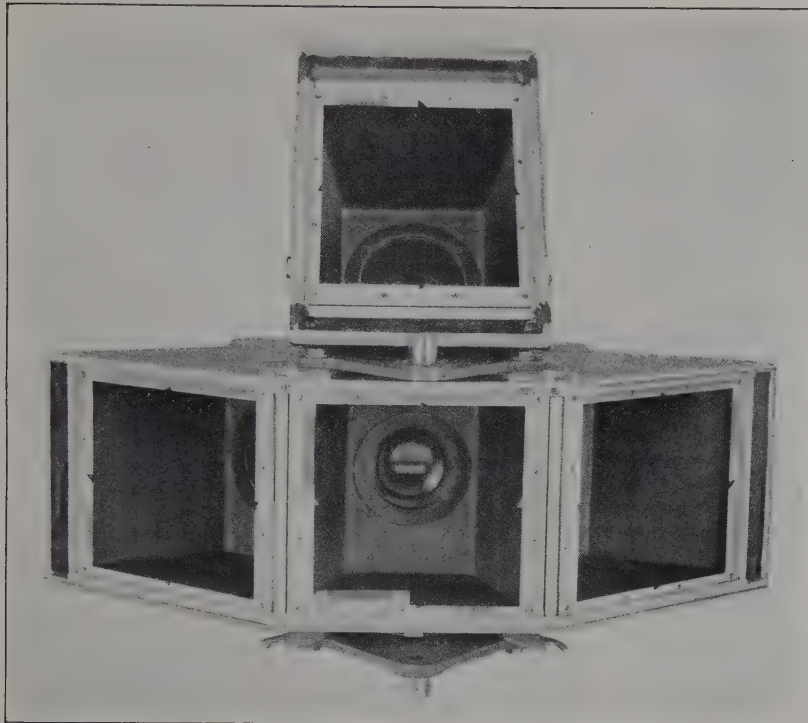
*A*



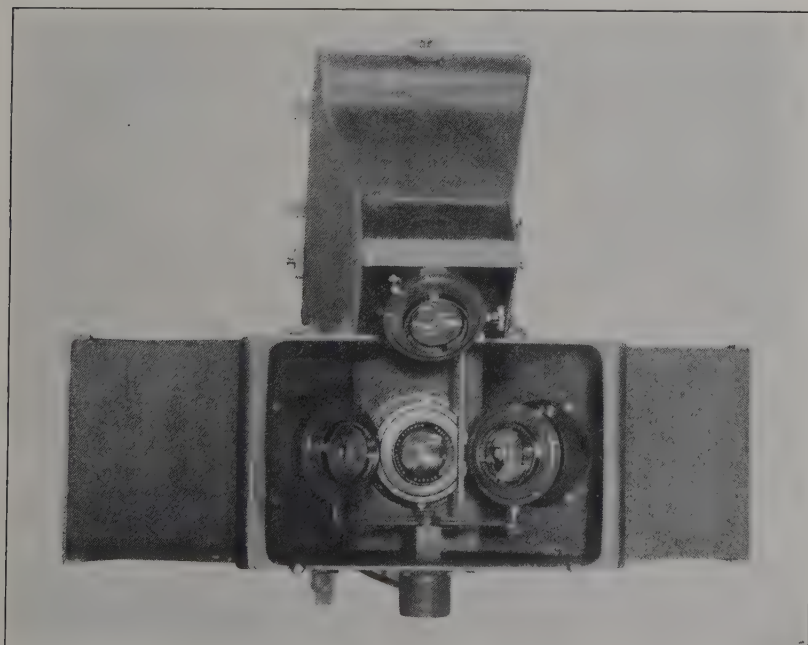
*B*

T-2 CAMERA

*A*, Rear view; *B*, front view



A

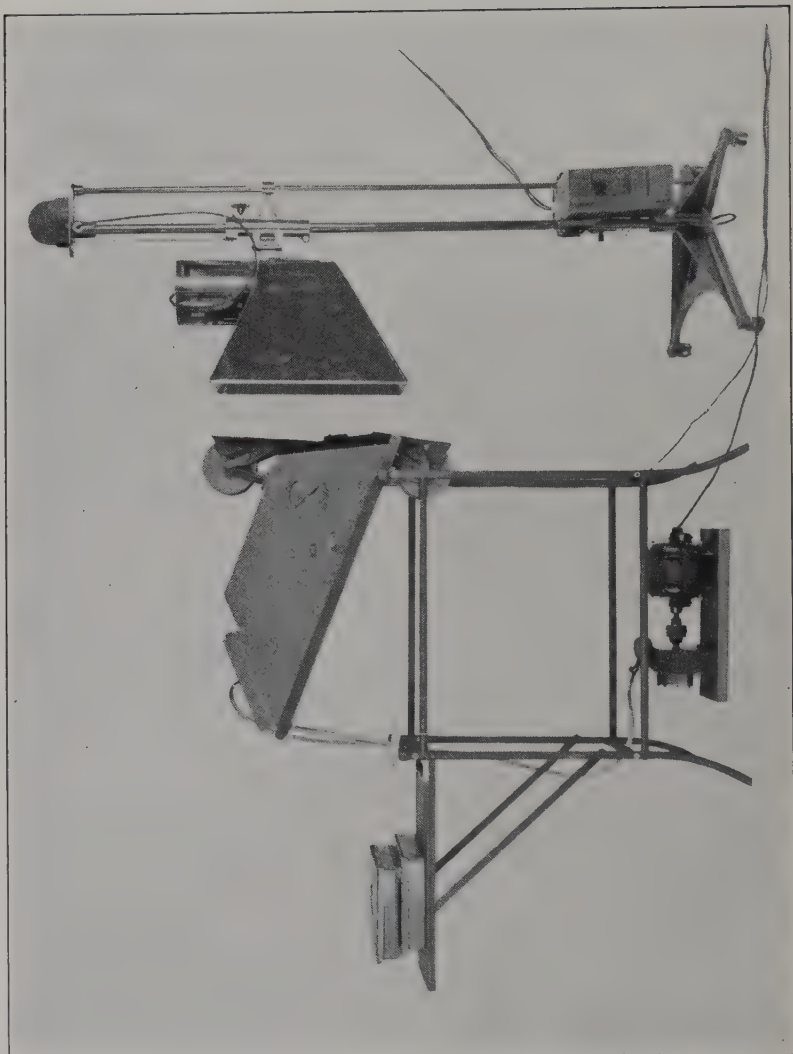


B

T-2 CAMERA

A, Focal planes and dark chambers; B, arrangement of lenses





THE FIXED T-2 TRANSFORMING PRINTER

shown in Plate 25, *B*. The two film-carrying spools are so mounted that they are on the vertical axis of the camera, with the take-up spool above the full spool. The film must be wound onto the empty spool by the hand crank shown in the illustration, as this camera is not of the automatic type. The film is guided in its journey from one spool to the other by several guide rollers in the magazines in addition to those in the base. The proper amount of film to be wound forward between exposures is indicated by one revolution of the dial shown above the hand crank in Plate 25, *B*. The film is held in the focal plane by three spring pressure plates which are provided with stops that prevent the pinching of the film between the focal planes and the pressure plates. The plate back of the B compartment is removable to facilitate the loading of the camera in the dark room. Two handholes with light-tight covers are provided on the sides of the magazine section for the same reason. The top of the camera is fitted with two level vials to aid the observer in keeping the camera in an upright position at each exposure and with an exposure counter and stop watch for recording the number and indicating the instant of each exposure. These devices are actuated by cams and gears on the shaft of the shutter-release mechanism.

The D unit of the T-2 camera is attached to the base of the camera on the side opposite the hand crank, with its optical axis at an angle of  $35^{\circ}$  with that of the B chamber. This arrangement places the focal plane of this unit at the same angle with the B plane as is made by the A and C planes and furnishes a photograph of the region back of the airplane. It is equipped with a lens identical in all respects with the A and C lenses, but has an independent film chamber and two film spools. The relation of this unit to the rest of the camera is shown in Plates 25, *A*, and 26, *B*. The shutter is synchronized with and actuated by the same mechanism as the B shutter, and the film is wound into position by the hand crank of the camera by an arrangement of bevel gears and a universal-joint shaft, also shown in Plate 25, *A*.

This camera uses hypersensitized panchromatic film in a roll 6 inches wide by 380 feet long, which is sufficient for 190 tri-lens exposures, and a shorter roll of the same width for the D unit. As this film is sensitive to light of all colors, it is necessary to load the camera in total darkness, and as its keeping quality is not good it should not be ordered until needed for use. It is kept under refrigeration at other times.

Color screens are used with this film to eliminate certain undesirable light rays and thus increase the ability of the film to record the details desired. These screens are in the form of thin gelatin

sheets and are inserted back of the front element of the lens. Several grades are available for use to compensate various atmospheric conditions.

The camera is provided with a suspension mechanism designed to reduce vibration and to make possible the leveling and orientation of the camera to obtain the most advantageous position for aerial mapping. This is accomplished by hanging the camera in a gimbal mount, which is equipped with rollers traveling on a circular track, and providing the entire apparatus with brackets and shock-absorbing cushions by which it may be attached to the fuselage of the airplane. These adjustments are necessary, for it is essential that the camera be placed in a predetermined position with respect to ground objects, with the axis of the B lens in an approximately vertical position. The azimuthal adjustment is important, as it is generally necessary to rotate the camera a few degrees in order to compensate for any wind effect on the airplane or to improve the angles of intersection, so that a more strongly adjusted map may be produced.

#### TRANSFORMER

The three oblique photographs made by a T-2 camera can not readily be used in topographic mapping until they have been reprojected into the plane of the B photograph. A special apparatus, which is both a camera and a printer but is usually called a transformer, shown in Plate 27, is used for this purpose. The spools on which the negative film is carried are shown on the end adjacent to the light source, and on the opposite end of the transformer is the suction back used to hold the photographic paper in the image plane of the lens. A motor and vacuum pump provide the necessary suction. The lens used in this transformer is of the wide-angle type, with a maximum stop opening of  $f/18$  and a focal length of about 7.5 inches. It is set in the interior of the transformer in a partition that divides the negative from the image end. The angles made by the negative and image planes in this transformer are unusual but are fixed by the focal length of the lenses used in the aerial camera and in the transformer and by the dihedral angle between the oblique and horizontal focal planes in the aerial camera. On account of this complex relation it is necessary to construct a transformer for use with each multiple-lens camera.

#### STEREOSCOPE

The interpretation of aerial photographs is much easier when overlapping prints are examined through a stereoscope, for this instrument has the peculiar property of causing the photographic

image to be seen in three dimensions. The third dimension, that of relief, is so strongly emphasized that differences of elevation as small as 50 feet can ordinarily be detected without magnification of the image, and with a special magnifying stereoscope very small differences can be seen and measured. The unusually strong stereoscopic effect obtained when aerial photographs are viewed through a stereoscope is due to the fact that the distance between the eyes (the "eye base") is increased in effect from a few inches to several thousand feet, as the observer sees the photographs as the terrain would appear to one whose eyes were separated by the distance between the exposure points of the two photographs. The magnification of the image by suitable lenses will increase this effect.

Stereoscopes of many different types are constructed, some being intended for use with glass negatives and transmitted light and others for use with photographic prints and reflected light. The high-powered instruments usually have very small fields; those of low power have larger fields. The Geological Survey has several stereoscopes using low magnifications, but by far the most useful is a simple mirror stereoscope of the Pellin type, which is not equipped with lenses for the magnification of the image. The Pellin stereoscope has four mirrors adjustably mounted on a bar and suitable standard in such a manner that by looking downward into two small mirrors the photographs can be seen by reflection in two larger mirrors. It has a large field of view, and the size of the image reaching either eye can be easily and quickly varied a small amount by a simple adjustment of the mirrors. The large field permits a better interpretation of the relief than can be obtained if only a small area appears in the field, and the variable magnification is helpful in the examination of those T-2 photographs that can not be viewed stereoscopically in the outer parts owing to differences in scale introduced by rolling of the airplane. Two such prints can often be brought to the same scale and a satisfactory stereoscopic view obtained by sliding the large reflecting mirrors along the bar on which they are mounted until a position is found that permits the merging of the two images.

Several forms of stereoscopic instruments have been designed for the purpose of making very exact measurements from aerial photographs that enable the topographer to complete the mapping of an area without field work other than the usual control surveys. This interesting phase of the subject of photogrammetry has not yet been undertaken by the Geological Survey.

### PHOTOGRAPHIC OPTICS

An elementary knowledge of the formation of an image by lenses is essential to a thorough understanding of photographs used in mapping, and this applies to photographs taken in the air or from



the ground. A short study of this subject will also explain the underlying principle of the stadia and of all other devices in which angular or linear measurements of an image in the plane of the reticle are made. Neither the use of the panoramic mapping camera nor the theory of the transformer can be clearly understood without a knowledge of this principle.

### OPTICAL DEFINITIONS AND FORMULAS

The optical axis of a lens is the path of a ray that will pass through the lens without deflection. In a well-centered lens the axis passes through the centers of curvature of the different lens surfaces.

If rays from a very distant object (such as the sun) are allowed to pass through a lens, the image will be formed in a plane called the secondary focal plane, or image plane. The primary focal plane can be found by reversing the lens and allowing the image to form on the opposite side of the lens. The intersections of the axis with these focal planes are the focal points of the lens and will be referred to as the principal points.

The two nodal planes are perpendicular to the axis and pass through the nodal points of the lens, which are designated the nodal point of incidence and the nodal point of emergence. One of the most interesting properties of the nodal points is that a ray entering the lens from any direction toward the nodal point of incidence will leave the lens parallel to its original direction but as if it had come from the nodal point of emergence. The location of these points can be found graphically by extending the incident and refracted ray to intersection with the optical axis, as shown in Figure 14, in which the nodal points of incidence and emergence for a double convex lens are designated by the letters  $N$  and  $N'$ , respectively. A study of this figure will show that regardless of the direction from which the ray approaches the nodal point of incidence it can be considered as leaving the lens from the other nodal point and parallel to its original direction. This property is utilized in measuring the focal length of a lens and in the construction of panoramic cameras, for it can be seen that a lens can be rotated about an axis passing through the nodal point of emergence without causing a movement of the image on a screen. The nodal points may fall outside as well as inside the lens, their separation and position being fixed by the type of lens under consideration.

The object and image planes are also perpendicular to the lens axis and as their names suggest are the planes in which are found the object and its image. These planes are conjugate and have a

fixed relation to each other that must be known in order to determine the scale of the image.

The equivalent focal length of a lens is the distance from the nodal plane to the image plane. The back focus is the distance between the rear surface of the lens and the image plane.

The focal length of a lens and the position of its nodal points can be readily determined on an optical bench and should always be known for all lenses used in mapping cameras. With a knowledge of these constants it is possible to determine the position and size of an image, either graphically or by computation. The graphic solution commonly used is as follows: A ray from *A* (fig. 15) parallel to the axis can be considered as passing through the lens as

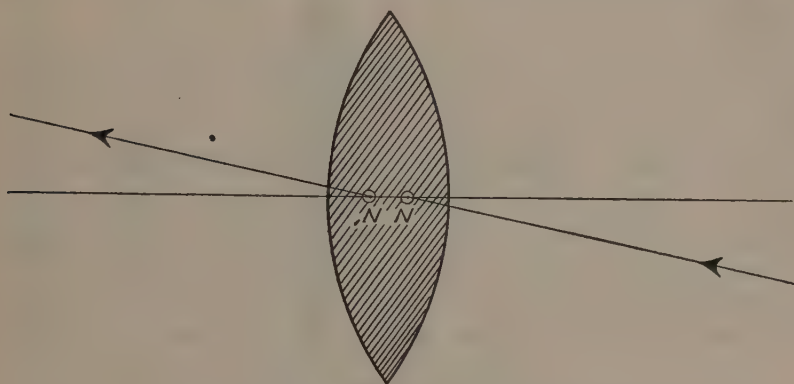


FIGURE 14.—Nodal points of a double convex lens

far as the nodal plane of emergence and there being refracted so that it passes in a straight line through the rear focal point. Another ray from *A* can be considered to travel straight through the front focal point as far as the nodal plane of incidence and from this point be parallel to the axis of the lens. The intersection of these two rays (*a*) is the location of the image of point *A*. In a similar manner the location of the image of point *B* can be found. The path of the actual rays through the lens is quite unlike this, although the location of the image is accurately given by this graphic method.

The primary and secondary focal points are shown in the same figure at *F* and *F'*, respectively; the distances from these points to the object and image planes are denoted by *x* and *x'* and the focal length is *f*. The distances *x*+*f* and *x'*+*f* are designated *p* and *p'*, respectively. With this notation it is evident that

$$\frac{\text{size of object } (AB)}{\text{size of image } (ab)} = \frac{p-f}{f} = \frac{f}{p'-f} \text{-----} \quad (1)$$

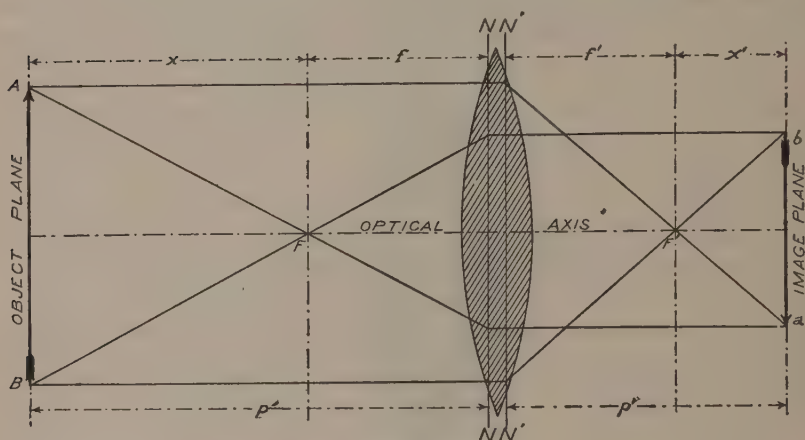
By equating the last terms and simplifying the expression it can be reduced to the easily remembered relation

$$\frac{1}{p} + \frac{1}{p'} = \frac{1}{f} \quad \text{-----} \quad (2)$$

It is also possible to derive from the figures the relations

$$\frac{\text{image size}}{\text{object size}} = \frac{p'}{p} \quad \text{-----} \quad (3)$$

$$f^2 = xx' \quad \text{-----} \quad (4)$$



*NN* = PLANE OF INCIDENCE  
*N'N'* = PLANE OF EMERGENCE

FIGURE 15.—Conjugate focal planes

As the scale of a map or aerial photograph is expressed as the ratio of size of drawing to size of original, equation 3 can be re-written as

$$\frac{1}{r} = \frac{\text{image size}}{\text{object size}} = \frac{p'}{p} \quad \text{-----} \quad (5)$$

where  $\frac{1}{r}$  denotes the scale.

The expression  $xx' = f^2$  is easily derived from equation 1 and is the condition that must be fulfilled in order to obtain a sharply focused image.

#### SCALE OF AN AERIAL PHOTOGRAPH

Equation 5 shows that the scale of an aerial photograph can be found from the ratio of distances to image and object planes when the measurements are made from the lens or from the ratio of the

length of a line measured on a photograph to the length of the corresponding line on the ground. The ideal condition of a horizontal plate and a horizontal ground surface must be assumed.

It is evident that under the conditions in which aerial photographs are made the distance from the camera lens to the object plane is the altitude ( $H$ ) of the camera and corresponds to the distance  $p$  in equation 5 and Figure 15. The substitution of widely separated values of  $H$  (or  $p$ ) in equation 5 will show that for all altitudes at which aerial mapping is done  $p'$  is practically equal to  $f$ , the focal length. This equation may therefore be written

$$\frac{1}{r} = \frac{f}{H} \text{-----} (6)$$

showing that the scale can be determined by dividing the focal length of the lens by the altitude of the camera. It is impossible to obtain very accurate determinations of the scale of aerial photographs by this method, however, as the only available knowledge of the altitude is that given by the altimeter (barometer) carried in the airplane. The method is readily used for approximate determinations if the camera has 12-inch lenses, for it follows that the scale is then the reciprocal of the altitude in feet. The most accurate results are obtained by scaling distances on the photographs and comparing them with the corresponding distances measured on the ground or scaled from an accurate map.

A photograph is a perspective representation of the objects appearing in it, and consequently has no uniform scale throughout unless the objects photographed are all in one plane that is parallel to the focal plane of the camera. This condition is so difficult of accomplishment in an aerial photograph that it is never fulfilled exactly, although good photographic flying over level areas will furnish aerial photographs that are nearly uniform throughout in the matter of scale. Uniformity of scale can not be obtained if differences of elevation exist within the area photographed, or if the camera axis is inclined, however slightly, to the vertical, and consequently the scale quoted for an aerial photograph must be considered only an approximation. It is evident that the top of a plateau or mesa will photograph to a larger scale than the valley land at its base, and for the same reason all photographs of any but very level land can not have a given scale throughout.

This variation in scale and other displacements that exist in the aerial photographs make it impossible to enlarge or reduce them successfully to any desired scale.



## SOME DISTORTIONS OF A PHOTOGRAPHIC IMAGE

Two types of aerial photographs are employed for mapping, differing only in the position of the camera axis at the moment of exposure. Photographs made with the axis within a few degrees of the vertical are called "verticals;" all others are called "obliques." As the condition of exact verticality of the lens axis is difficult to fulfill, the term "verticals" is now used to designate photographs that are made with the lens axis in an approximately vertical position. Photographs obtained while every effort is being made by the pilot and observer to maintain the camera axis truly vertical are the so-called "verticals"; those made with the axis intentionally inclined are the "obliques."

A truly vertical photograph of a horizontal ground surface—that is, a photograph taken when the photographic plate is exactly horizontal—is a reduced copy of the original and is, in a sense, a map, as it is a reduced horizontal projection of the original. If the camera axis is not exactly vertical or the terrain photographed is not horizontal this condition is not fulfilled, and a photographic image is obtained that shows the ground features in improper relation. Fortunately these displacements follow definite mathematical and geometrical rules and can be corrected if the factors causing the displacements are known.

If angles between points on a photographic plate are measured at its center it can be proved that they equal the corresponding horizontal angles that would be measured by a transit, providing that the photographic plate was horizontal and vertically above the transit station when the photograph was made. If  $A, B, C$ , Figure 16, represent three points on a horizontal ground surface subtending the angles  $ANB$  and  $BNC$  at the point  $N$ , which is vertically below the aerial camera and is therefore called the nadir point, and  $a, b, c$ , represent the corresponding images of these points on the horizontal plate, it is evident that the angles  $appb$  and  $bppc$  on the plate will equal the angles  $ANB$  and  $BNC$  on the ground. This equality of corresponding angles also exists whatever may be the elevation of points  $A, B$ , and  $C$ , for although the points may be displaced on the plate by their position above or below the datum plane, these displacements are radial and do not affect the size of the subtended angles. That this is true can be seen by reference to Figure 17. In this figure,  $A$  is the high point,  $A'$  its projected position in the datum plane,  $ppN$  a vertical line passing through the lens and perpendicular to both the photographic plate and the datum plane;  $a'$  is the image of point  $A'$  and  $a$  the image of point  $A$ . The figure shows that the difference of elevation  $AA'$  causes the image point to

be displaced on the plate from  $a'$  to  $a$ , and as  $A$  is vertically above  $A'$ , the triangles  $AOA'$  and  $aOa'$  are in a vertical plane which is perpendicular to the plate and which contains the line  $ppN$ . This being so,  $a$  and  $a'$  must be on a radial line passing through the plate center  $pp$ , and thus the displacement due to the difference of eleva-

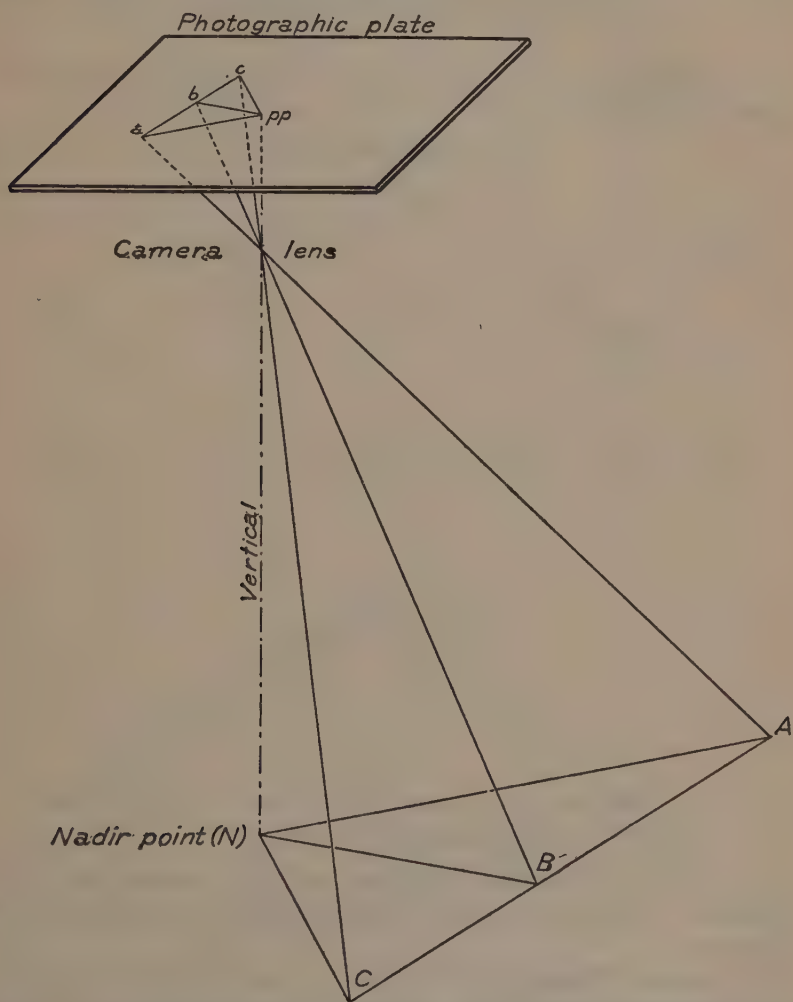


FIGURE 16.—Relation of angles on photographic plate to corresponding angles on the ground

tion can not affect the value of angles measured at the center of the photograph. The amount of image displacement due to the elevation of an object can be easily found from Figure 17. Let the angle  $AA'A' = \alpha$ , which is identical in value with the angle  $ppaO$ , as they are alternate angles. The altitude of the camera lens is  $E$ , and its

focal length,  $ppO$ , is  $f$ . The following equations are easily derived from this figure:

$$\frac{aa'}{A'A''} = \frac{f}{E} \quad \text{-----} \quad (7)$$

$$A'A'' = \frac{AA' \sin (90^\circ - \alpha)}{\sin \alpha} \quad \text{-----} \quad (8)$$

The substitution of the value of  $A'A''$  given by equation 8 in equation 7 gives

$$aa' = \frac{f[AA' \sin (90^\circ - \alpha)]}{E \sin \alpha} \quad \text{-----} \quad (9)$$

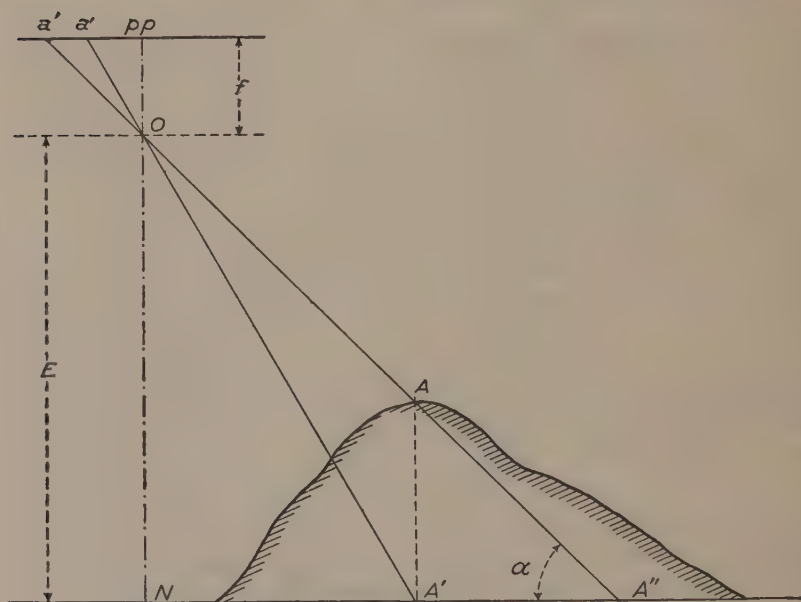


FIGURE 17.—Displacement of photographic image due to relief

The value of  $\alpha$  can be computed, for the abscissa  $app$  can be measured on the plate, and the focal length of the camera,  $f$ , will be known.

The amount of image displacement to expect can also be found by the chart shown as Plate 28. Its use will be apparent by reference to the key given on the chart itself.

Any inclination of the camera axis will distort the angles on the plate and render them useless for all purposes that demand exactitude in this regard. The angles are sufficiently accurate for small-scale mapping, however, if the tilt of the camera is not more than is ordinarily encountered in good photographic flying. A skilled pilot may be expected to keep his airplane within  $3^\circ$  of the horizontal,

and as long as this angle is not exceeded no difficulty due to erroneous values of the central angles will be encountered in the use of the photographs. The effect of a tilt at right angles to the direction of flight is shown in Figure 18, in which the tilt is assumed as the large amount of  $10^\circ$  in order to render the effect more apparent. The lower portion on this figure shows in vertical section that when the

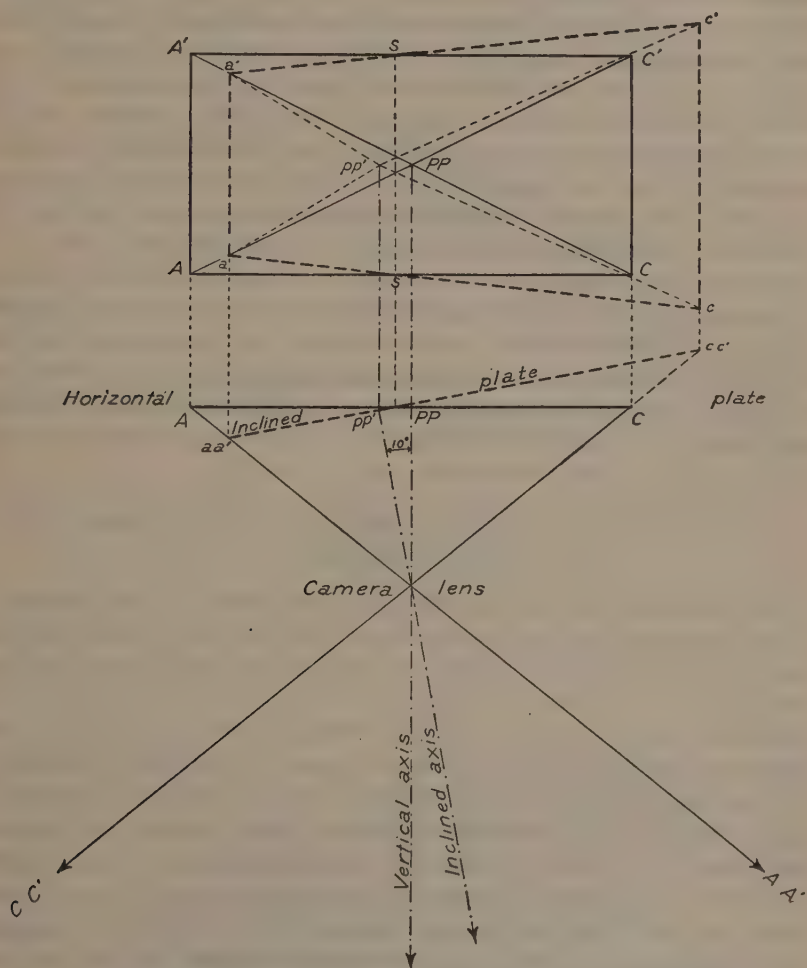


FIGURE 18.—Displacement of photographic image due to tilt

camera axis is tilted images on one side of the plate are enlarged while those on the other side are correspondingly reduced. The effect of this distortion of the image is more forcibly indicated by the horizontal projection in the upper portion of the figure. The shape of the ground figure is correctly represented by AA'C'C, in which the side C'C is equal to AA'. The inclination of the camera dis-



torts the figure, however, and  $aa'e'$  results, in which the side  $aa'$  is shorter than the side  $e'e$ , obviously an incorrect representation. The figure also shows that the tilt of the axis causes the principal point of the plate to move from  $PP$  to  $pp'$  and therefore distorts all angles measured from this point. This change in the value of the angles can be seen when the dotted lines radiating from  $pp'$  are compared with the corresponding solid lines from the point  $PP$ . Fortunately, very small tilts do not affect these angles so much that their usefulness for small-scale mapping is entirely lost, and consequently any point near the principal point of the photograph may be selected as the station point for the photograph. Further inspection of the figure will show that a line across the photograph midway between  $PP$  and  $pp'$  perpendicular to the direction of tilt is the only line on the inclined photograph that has the same scale as the horizontal photograph. This line, shown in the figure as  $SS$ , is of very great importance in the transformation of the oblique A, C, and D photographs of the T-2 camera, for as it is already at the desired scale the problem becomes one of reducing and enlarging the rest of the photograph where needed while holding this line unchanged. On account of this peculiarity the line is often called the "line of equal scale," or simply the "scale line," and its distance from the principal point is the distance  $PP-S$ .

### CONTROL FOR MAPS COMPILED FROM AERIAL PHOTOGRAPHS

The successful compilation of maps from aerial photographs is largely dependent on the character of the traverse or triangulation upon which it is based. Both types of control can be used successfully.

Transit traverse for the control of aerial photographs does not differ greatly from that used in the past for the control of topographic maps, the principal differences being in the character of the points and the location of the lines. Road corners or intersections, streams or railway crossings, fence lines beaten out by cattle or defined by a growth of brush, sharp angles in wood lines, or lone evergreen trees standing entirely isolated are all easily recoverable on the photographs. Buildings are in the doubtful class, as they are not positively identifiable, especially when standing in a group. Many points commonly used in the past are useless in controlling photographs. Among these are gates, nails in tree roots, and iron posts or tablets set in rock. Where tablets or iron posts are located near road corners or other points that are easily distinguished on the photographs, these points should be used as reference for the permanent points. Nothing is superior to a road intersection in sectionized country.

Single-lens photographs can usually be well controlled by a transit-traverse line around and across the center of the quadrangle, but for multiple-lens photographs the best control is obtained only when points are so located that they will be found on the center and on each oblique print both at the beginning and end of each flight, and this combination is often not attained when the traverse line is run before the photographs are made. When the flying has been done well in advance of the time the field work will start it is advisable to make a sketch, based on the photographs, showing the most advantageous location of the traverse lines for the guidance of the control party. This may necessitate placing the line 1 or 2 miles inside or outside of the edge of the quadrangle, depending on the location of the photographs, but it will insure a more easily and more accurately controlled map than would otherwise be obtained.

The control of a quadrangle by graphic plane-table triangulation has certain advantages to the map compiler working with T-1 or T-2 photographs and probably is more accurate than control by transit traverse. This greater accuracy is due to the fact that by triangulation numerous points can be located within the quadrangle and used as checks on the compilation and thus prevent the accumulation of errors of position. The plane-table triangulation must be carefully done, for the control sheet must be able to stand enlargement to a scale of about 1:20,000, the scale at which the photographic compilation is usually made. It is advisable, particularly in wet or humid climates, to have the control sheets mounted on zinc before the projection is made, as that assures a sheet free from paper distortion.

Flags in trees, water tanks, church steeples and similar points can not be recovered positively in small-scale photographs and should be located by reference to something that can be identified. Sharp-topped hills or peaks can often be distinguished on the photographs with a stereoscope and successfully used. An accurate sketch of the fences, roads, and woodland around a located point is more valuable in identifying the point than any description can be.

## PHOTOGRAPHING A QUADRANGLE

### REQUIREMENTS FOR FLYING

The successful flying over a quadrangle for the purpose of mapping calls for rare skill on the part of the pilot and a thorough knowledge of the use and care of the camera on the part of the observer, with fine teamwork between the two. For this work a pilot must have not only ability to fly his airplane but knowledge of the undesirable effect that certain movements of the airplane have

upon the photographs and the proper procedure to take to avoid them. There is nothing more discouraging to one who must compile the base maps from aerial photographs than the receipt of a shipment of photographs that immediately display the pilot's unfamiliarity with photographic flying or his carelessness. Inability to keep the airplane on an even keel, "banking" on the slight changes in direction that are made in attempting to keep on a predetermined course, and continuous changes in altitude are all very clearly indicated on the photographs and with an exactness far beyond that of any indicating instruments that may be carried in the airplane. The speed and accuracy with which a base map may be compiled being largely influenced by these factors, it is essential that the pilot should clearly realize their effect and fly his airplane in such a manner that it will be minimized. An exact knowledge of his position at all times and ability to recognize landmarks and fly by them can be acquired by practice and are essential to the photographic pilot.

In sectionized country photographic flying is best done in the north or south direction. This is specially important for work done with the single-lens camera, as the photographs can be worked up with greater ease and more valuable comparisons can be made with section-line measurements than is possible when the flights are directed east or west. For flights along stream valleys, where only the course of the stream is to be mapped, or for flights over country that has not been sectionized, courses can be chosen that are most convenient to the pilot, and with regard to the layout of control, existing or proposed, although in flying along a stream the changes in direction should be made with as little banking of the plane as possible.

The question of the correct exposure to be given to an aerial photograph is fixed not so much by the lighting of the subject as it is by the exposure necessary to "stop" the movement of the image on the film. A photographic airplane flying at 80 miles an hour is moving at a rate of 117 feet a second. When flying at 12,000 feet with a camera having a 12-inch lens the image of a given point on the ground will move a distance of about 0.12 inch on the plate in 1 second. To make a sharp picture it is essential that the shutter exposure be short enough to prevent any blurring of the image on account of this movement, and it has been found that  $\frac{1}{150}$  of a second will easily accomplish this end and will ordinarily prevent any indistinctness due to vibrations that are transmitted to the camera through its shock-absorbing suspension. In order that the aerial photographic work may be carried on at any time during reasonably clear weather, hypersensitized panchromatic film is used, and the



cameras are equipped with lenses having maximum stop openings of  $f/4.5$  and light filters of various degrees of absorption. American aerial cameras are commonly equipped with "between the lens" shutters, for these, although not so efficient as the focal-plane shutters, do not cause distortion of the image by their method of operation. This disadvantage of the focal-plane shutter is more theoretical than real for small-scale mapping, however, for the flying is done at so great an altitude that the movement of the image is slow and the resulting distortion consequently very small.

To compute the altitude at which he should fly in order that the photographs may be made at a predetermined scale, it is essential that the pilot should know the general elevation of the country over which the work will be done and the exact focal length of the camera lens. The fact that a camera has, for example, a 12-inch or a 6-inch lens is not sufficient to fix more than approximately the altitude at which the photography should be undertaken. The exact value of the focal length of every camera lens used for mapping should be obtainable by the pilot or observer from the records of his office. The altitude at which the flying should be done in order to obtain the desired scale can be determined by the relation

$$\text{Altitude} = \frac{f}{r}$$

in which  $f$  is the focal length in feet and  $r$  the scale expressed as a fraction.

In hilly country it is impossible to have the photographs at a constant scale throughout, but by selecting the mean elevation of the country as a datum plane for determining the scale, the variations in this respect will be at a minimum.

After the altitude at which the flying should be done has been determined it is the pilot's duty to find and maintain this altitude while the photographs are being made. The accuracy of the altimeter will determine how nearly the desired altitude can be approached, and its readiness in responding quickly to small changes of altitude will determine how closely the altitude can be maintained. Although every change in level of the airplane is indicated in the photographs as a change in scale, this difficulty is probably the least troublesome of all with which the map compiler must contend and apparently is the feature in which photographic pilots approach nearest to perfection. The small-scale changes that are always to be expected in aerial photographs do not increase the difficulty of compilation or introduce errors of any kind in the resulting map when T-1 or T-2 photographs are used, for all compilation with these



photographs is based on the radial-line method, which is independent of the scale of the prints. Differences in scale on single-lens photographs, however, seriously affect the compilation, as there is no economical way of reducing them to a common datum. It is possible to eliminate such differences from single-lens photographs having a scale of 1:10,000, or less, by using the intersection method, providing that large end and side overlaps were obtained by the pilot and that numerous well-determined control points exist upon which to base the compilation. But this is very expensive, and for several other reasons this method can not economically be used with single-lens photographs in small-scale map compilation. The area covered by a single-lens photograph is relatively small (see table on p. 399), and consequently it is necessary to space the control points closely in order to get at least three points on each photograph at the beginning of each flight. Where this distribution of points is available and the overlaps are sufficiently large the graphic control net can be extended with accuracy for several miles, and this distance would be greatly increased if it were possible to work from the negatives and have the advantage of using the proper stereoscopic instruments. For the sake of accuracy and ease of compilation it is well to have another line of control across the center of the area to be mapped that will serve as a check on the accuracy of the graphic control and as a basis for a new start. On a 15-minute quadrangle this will call for three lines of control across the area with computed points at intervals of not more than half a mile and preferably closer. Another serious difficulty is that of the time demanded to work up a satisfactory strong control net with the large number of photographs that must be handled. Still another lies in the skill needed to maintain accurate orientation of the prints with the short lines available. This difficulty arises from the fact that the longest line that can be used for orientation is equal to the semidiagonal of the photographic print. This distance is about 5 inches, whereas the centers of adjacent photographs will ordinarily be separated by 3 inches. This gives a ratio of 5 to 3, which is too low to give the accuracy that can be obtained from tri-lens photographs having a ratio of 5 to 1.

*Areas covered by aerial-mapping cameras*

Single-lens camera, 18 by 24 centimeter (7 by 9 inches net), 12-inch focus					Three-lens camera (T-1), 6.4-inch focus				
Altitude (feet)	Scale	Major axis (miles)	Minor axis (miles)	Area (square miles)	Altitude (feet)	Scale	Major axis (miles)	Minor axis (miles)	Area (square miles)
9,000	1: 9,000	1.278	0.994	1.270	7,000	1:13,125	3.977	1.139	5.41
9,250	1: 9,250	1.314	1.022	1.343	7,250	1:13,594	4.119	1.180	5.80
9,500	1: 9,500	1.349	1.049	1.415	7,500	1:14,062	4.261	1.221	6.21
9,750	1: 9,750	1.385	1.077	1.492	7,750	1:14,531	4.403	1.261	6.63
10,000	1:10,000	1.420	1.105	1.569	8,000	1:15,000	4.545	1.302	7.06
10,250	1:10,250	1.456	1.132	1.648	8,250	1:15,469	4.688	1.343	7.51
10,500	1:10,500	1.491	1.160	1.730	8,500	1:15,937	4.829	1.383	7.97
10,750	1:10,750	1.527	1.188	1.814	8,750	1:16,406	4.972	1.424	8.45
11,000	1:11,000	1.562	1.215	1.898	9,000	1:16,875	5.114	1.465	8.94
11,250	1:11,250	1.598	1.243	1.986	9,250	1:17,344	5.256	1.506	9.44
11,500	1:11,500	1.633	1.270	2.074	9,500	1:17,812	5.398	1.546	9.96
11,750	1:11,750	1.669	1.298	2.166	9,750	1:18,281	5.540	1.587	10.49
12,000	1:12,000	1.705	1.326	2.261	10,000	1:18,750	5.682	1.628	11.06
12,250	1:12,250	1.740	1.353	2.354	10,250	1:19,219	5.824	1.668	11.59
12,500	1:12,500	1.776	1.381	2.453	10,500	1:19,687	5.966	1.709	12.16
12,750	1:12,750	1.811	1.409	2.552	10,750	1:20,156	6.108	1.750	12.75
13,000	1:13,000	1.847	1.436	2.652	11,000	1:20,625	6.250	1.790	13.35
13,250	1:13,250	1.882	1.464	2.755	11,250	1:21,094	6.392	1.831	13.97
13,500	1:13,500	1.918	1.491	2.860	11,500	1:21,562	6.534	1.872	14.59
13,750	1:13,750	1.953	1.519	2.967	11,750	1:22,031	6.676	1.912	15.23
14,000	1:14,000	1.989	1.547	3.077	12,000	1:22,500	6.818	1.953	15.89
14,250	1:14,250	2.024	1.574	3.186	12,250	1:22,969	6.960	1.994	16.56
14,500	1:14,500	2.060	1.602	3.300	12,500	1:23,437	7.102	2.034	17.24
14,750	1:14,750	2.095	1.630	3.415	12,750	1:23,906	7.244	2.075	17.94
15,000	1:15,000	2.131	1.657	3.531	13,000	1:24,375	7.386	2.116	18.65
15,250	1:15,250	2.166	1.685	3.650	13,250	1:24,844	7.528	2.157	19.37
15,500	1:15,500	2.202	1.712	3.770	13,500	1:25,312	7.670	2.197	20.11
15,750	1:15,750	2.237	1.740	3.892	13,750	1:25,781	7.812	2.238	20.86
16,000	1:16,000	2.273	1.768	4.019	14,000	1:26,250	7.955	2.279	21.63
16,250	1:16,250	2.308	1.795	4.143	14,250	1:26,719	8.097	2.319	22.41
16,500	1:16,500	2.344	1.823	4.273	14,500	1:27,187	8.239	2.360	23.20
16,750	1:16,750	2.379	1.850	4.401	14,750	1:27,656	8.381	2.401	24.00
17,000	1:17,000	2.415	1.878	4.535	15,000	1:28,125	8.523	2.441	24.83
17,250	1:17,250	2.450	1.906	4.670	15,250	1:28,594	8.665	2.482	25.66
17,500	1:17,500	2.486	1.933	4.805	15,500	1:29,062	8.807	2.523	26.51
17,750	1:17,750	2.521	1.961	4.944	15,750	1:29,531	8.949	2.563	27.37
18,000	1:18,000	2.557	1.989	5.086	16,000	1:30,000	9.091	2.604	28.25

**CHOICE OF SCALES**

The scale that should be chosen depends largely on the use for which the photographs are intended. The single-lens type of photograph is usually needed in regions where there is a great concentration of culture, as in cities, and where there is need for extreme sharpness of image. It has been found that a scale of 1:12,000 is sufficiently large to show all the detail that can be included on the map, and on this scale it is possible to cover a sufficient area at each exposure without flying at extreme altitudes. The multiple-lens photographs allow a great variation of scale owing to the short focal length of the lens used with this type of camera. Scales as small as 1:31,680 can be obtained with this camera without requiring the pilot to fly at extraordinary heights. A scale as small as this is advantageous, inasmuch as with it the quadrangle is covered by fewer photographs and less ground control is needed. Experience has indicated, however, that larger scales will serve the topographer's need better, as it is difficult to distinguish buildings and other small

objects on a scale of 1:31,680. A scale of 1:20,000 or slightly smaller seems very satisfactory for the compilation of maps for publication on a scale of 1:62,500, as all necessary detail can be distinguished easily on the photographs, and a 15-minute quadrangle can still be covered by three flights of the airplane. With this scale, the sheet on which the base map is drafted is small enough to be easily handled, but that is hardly true with a scale much larger.

#### OVERLAPS AND "CRABBING" OF PHOTOGRAPHS

A large overlap of the photographs in the direction of flight is absolutely essential to map compilation by the radial-line method, for every point must appear on at least three consecutive prints of a flight in order to make this method operative. This can be accomplished only by so timing the exposure that the overlap shall never be less than about 60 per cent. An overlap of less than 50 per cent is equivalent to a shutter failure so far as the compilation is concerned, for it halts the progress of the work just as effectively as a missing photograph. A lateral overlap is also necessary, in order that adjacent flights may completely cover the area to be photographed, without leaving a strip of unphotographed country between them. This lateral overlap should preferably be about 30 per cent, which effectively ties the two flights together and strengthens the entire net of graphic control. Smaller overlaps than this have the disadvantage of giving weak ties between the flights and should therefore be avoided. The size of the angles of intersection between flights can be somewhat increased by rotating the camera in its mount so that it makes an angle of  $10^{\circ}$  to  $15^{\circ}$  with the direction of flight. This procedure is particularly valuable with the T-1 type of photograph but is not so necessary with the T-2 type. Rotation, or "crabbing" of the camera, as it is sometimes called, should not be allowed to exceed  $15^{\circ}$ , however, as a greater angle renders it extremely difficult to control the photographs by the usual method of running transit control lines.

#### LABORATORY WORK

The development and fixing of the exposed negatives need not be considered here, as the process does not differ greatly from the usual method of developing panchromatic film or plates and has no bearing on the work of the topographer. The fact that the film is in rolls ranging in length from 100 to 380 feet makes it necessary to develop the film by the tank method and is probably the most unusual feature of this work.

### NUMBERING THE NEGATIVES

The films must be numbered in order to identify the prints and to show the order in which the exposures were made. If the job is a large one in which several rolls of film were used the rolls may be numbered separately, and then the consecutive exposures, beginning with 1 for each roll, but consecutive numbering throughout a job is much simpler and more satisfactory to the map compiler. The film from multiple-lens cameras must be numbered in triplicate or quadruplicate, as the A, B, C, and D prints of each exposure must carry the same number. The numbering is done on the margin of the film in a space provided for that purpose adjacent to the shadowgraph showing the camera number. The figures should be put in with black India ink in order that the numbers may print sharply. The single-lens photographs can be numbered in any corner, although it is helpful to have the number always appear in either the northeast or the northwest corner, as this indicates the north direction on the print and is thus a great time saver.

### TRANSFORMATION OF OBLIQUE NEGATIVES

The transformation of the oblique A, C, and D negatives and the contact printing of the B negatives is the next step in the preparation of the photographs and is another photographic process in which the topographer is only indirectly interested. The transformation has been so greatly simplified that it is now not much more difficult than contact printing. The careful registration of the negatives with certain index marks in the camera is the only step calling for special care, but this must not be slighted if the A, C, and D prints are to match the B prints properly. Even a slight inaccuracy in the adjustment of a negative in the holder will so distort the print that it will be useless for intersection work.

### INDEX MAPS OF AERIAL FLIGHTS

After transforming the negatives the pilot and photographer must prepare an index sketch, or map, on which is shown the approximate location of each strip flown, the direction of flight, and the numbers of the prints at the beginning and end of each strip. This is most easily done by making the index on the best map available, but if no map exists a sketch of the quadrangle should be made and the area covered by each flight indicated. This sketch should give also the date and hour of the flight, as these data are sometimes needed in the compilation.



### OFFICE PROCEDURE

The unmounted prints and the index map are then sent to the compiling office, where they are mounted and indexed preparatory to the map compilation. The mounting can not be undertaken without a knowledge of the correct alinement and the proper separation of the A, B, C, and D prints. The position that the prints must have in relation to each other when mounted varies slightly for different cameras but is a fixed relation for any one camera. A drawing showing the proper position of the four indexes of each photograph is prepared and used as a copy in the preparation of lithographic prints on heavy paper. The prints are trimmed and "dry mounted" on these sheets, with each axis of the individual photographs superimposed on the corresponding axial line on the mount. Oblique prints that have been correctly transformed and mounted will make a perfect joining with the image on the B print, and the axes of all will fall in the proper positions on the mount. The failure of the assembled composite print to meet these conditions indicates faulty transformation and can be corrected only by a retransformation. As the successful use of multiple-lens photographs depends largely on their mounting, it is important that great care be given to this part of the work.

The assembled composite multiple-lens photographs or the single-lens prints, as the case may be, are numbered consecutively and then filed until they are needed for map compilation. The numbers are entered on cards, which are filed by quadrangles or projects and which contain all pertinent information regarding the aerial photographs and the map compilation to be based on them.

### COMPILATION OF MAPS FROM AERIAL PHOTOGRAPHS

Aerial photographs can be assembled for use in compiling a map in various ways. Experience acquired during several years indicates that it is necessary to select that method of compilation which will give the most accurate determination of positions for each individual area. The conditions that largely control this selection are the type of photograph and the relief of the area to be mapped. The lack of horizontality of the photographic film at the moment of exposure affects the usefulness of the photographs severely, but as this condition reflects the skill of the pilot and the flying conditions at the time it can not be accurately determined in advance by the map compiler. However, when the photographs are known to be badly distorted by tilt this fact should be kept in mind in selecting the method of compilation. The methods commonly used by the Geological Survey in compiling maps from aerial photographs are referred

to as the straight-line method, the section-line method, and the radial-line method. For some uses a picture is more valuable than a map, and a mosaic should be constructed.

### STRAIGHT-LINE METHOD

The straight-line method can be most advantageously used to assemble aerial photographs of the single-lens type having large overlaps, in which the distortion of the images due to tilt of the camera or to relief of the terrain is a minimum. To utilize this method it is well to regard the photographs extending from one known control point to another control point as portions of a traverse line. The evenness and regularity with which the photographic work was accomplished and the amount of ground relief will then determine whether it is best to use a single straight line throughout for orientation, or to break the flight up into several smaller sections. For a country of small surface relief it will generally be possible to utilize a single straight line for orientation of the photographs.

The principal point of each photograph should be located approximately by drawing its two diagonals, after which the photographs should be laid out in regular order on a large table and fitted together as accurately as possible by photographic images alone. A straight edge is then placed on the assembled photographic strip and so adjusted that its edge will pass as closely as possible to the principal point of each of the photographs, the fact being kept in mind that a well-selected line should have an equal number of principal points at equal distances to each side. The line indicated by the straight edge should be transferred to the end photograph that is uppermost in the strip of photographs, by carefully drawing a fine sharp line along the straight edge. This line is drawn on only one photograph. The photographs are then taken up from the drafting table in order to extend the straight line onto each photograph in turn. On the straight line drawn on the first photograph and in the region overlapped by the second photograph two points as far apart as possible are selected. These points should be very sharply defined, in order that they can be positively identified on the second photograph. Through these two points so identified on the second photograph a fine sharp line is drawn and produced to each side of the photograph. This process is repeated with the second and third photographs, and so on until such a line has been drawn on each photograph in the strip. There now appears on each photograph a line that is identical in azimuth with the lines on all the other photographs. A straight line is then drawn on any large sheet of paper as a guide, and the first photograph is placed over it, so oriented that the line on the photograph will coincide with the line on the paper.

This photograph should be held in place in any convenient manner, and the second photograph should be similarly adjusted over the guide line and slipped along with the same orientation, until any point on or near this line is exactly above the same point on the first photograph. The process is repeated with the third and succeeding photographs. These photographs are then as accurately joined as is possible by this method and should be permanently fastened together in this position.

It is often impossible to utilize a single straight line from beginning to end of a flight on account of the disposition of the photographs. If the airplane was badly "crabbed" with respect to the line of flight on account of adverse winds, or if the line of flight was irregular, it will be found impossible to select a single straight line that will not depart a considerable distance from the line of principal points. In this event a line should be selected that will fulfill the desired condition for as large a number of adjacent photographs as possible, and one or more additional straight lines should be similarly selected for the remainder of the strip. Usually two lines will be sufficient to control a strip of the length ordinarily occurring between fixed control points.

In any event the entire strip of photographs extending between fixed control points should be laid out and fitted together by photographic images as described above for orientation by a single straight line. The directions of the two or more guide lines can then be determined from inspection of the principal points of the photographs, and the one or more photographs on which an intersection of the guide lines should be located can be selected. The guide lines should then be transferred to the one or more photographs on which bends in the composite guide line occur, making the intersections or bends at the principal points of the photographs. Working in both directions from the photograph on which the first bend occurs the guide lines should be transferred to each photograph in turn as described above for a single guide line. If more than two guide lines are necessary, the transfer of the second guide line should be duplicated, working forward from the first bend and backward from the second, and the best possible adjustment should be made in the final orientation. The angles between adjacent guide lines are obtained from the photographs on which the bends occur. The first angle should be reproduced on the guide sheet and the courses carefully extended. The photographs are then oriented and adjusted as described above for a single guide line except that the work is started at the first bend and carried in both directions. If more than two guide lines are used, the adjustment of the photographs along the second course should be carried to the second bend. If



there is an appreciable difference between the projected guide line and the one originally drawn at the second bend the photographs should be readjusted, beginning at the second bend and working backward until the discrepancy disappears. In any event the adjustment of the third course should be commenced at the second bend and carried forward from the original position and direction of the plotted guide line.

The best location of the control points with respect to the guide line and the centers of the photographs will be obtained by intersecting the control points from the principal points of the photographs on which they appear. These intersections are made on the sheet on which the guide line is drawn. Location of the control points by this method is particularly important if these points fall near the edges of the photographs.

The data desired from this strip mosaic, as it is commonly called, can then be reduced to the scale of the map either by pantograph or by photography, the amount of reduction being determined by comparing the map distance between the control points with the distance indicated on the photographs. If the reduction is made photographically, it will be necessary to trace in ink the data desired before reduction. This process gives a narrow strip map showing an area extending between known control points on a scale that very closely approximates the scale of the map that is to be drawn. This strip map is very much like a road traverse by a topographer who has extended his sketching out to a distance of three-quarters of a mile to each side of his plane-table stations, except that no contours are shown. A number of such interlocking strip maps should be considered, in adjusting them to the base map, as so many traverse lines, and they will require the same consideration in adjustment that is given to plane-table traverse. It will be found, however, that the photographic strip maps will have very small discrepancies in scale, probably not over 50 or 100 feet, and they can easily be adjusted to true distances.

In many areas known control points may not be available for determining the mean scale of the photographs, or for fixing the strip in proper position on the compilation sheet. The proper procedure under such conditions can be determined only after a careful study of the material and data available. In general, the photographic strips on which two or more control points occur should be adjusted first. The photographic strips without control will then be dependent on these adjusted strips for position and scale. If the photographs reveal any straight lines, such as roads, railroads, or section or fence lines, passing from one adjusted strip to another, these should be carefully noted, as they are of very great help to



the map compiler in fixing the scale and orientation of all the map detail in their vicinity. The intervening strips are compiled by the usual straight-line method, definite points that exist on both the controlled and the uncontrolled strips being used as a basis for determining the scale for the new strip. A single strip can be added on each side of an adjusted strip in this way, and these in turn will serve to adjust other strips. All the skill and judgment possessed by the compiler will be called into use to obtain even a reasonably good adjustment under such conditions, and if the distance between adjusted strips is more than 3 or 4 miles the positions shown on the resultant map will not be of great accuracy. If the area has been covered by the section lines of the public-land system the problem is simple, as explained below.

The straight-line method will fail absolutely or will result in a poor orientation of the photographs if a large overlap between successive photographs is not obtained throughout the flight. The distances measured along the strip map in the direction of flight will be fairly accurate if the country being mapped is flat, but they will not be uniform in scale throughout if it has considerable relief.

#### SECTION-LINE METHOD

The section-line method will give excellent results with photographs of either the single-lens or multiple-lens type, if it is possible to reconstruct accurately the net of section lines from the notes of the original survey, and if these lines or their corners can be identified on the photographs. Roads or fences known to be on section lines offer the best means of identification on the photographs. If the section lines are not marked on the ground so as to show on the photographs, it will be necessary in advance of the flying to mark the section corners by large white markers, such as white cloth banners or whitewash crosses on the ground or white banners in trees.

With a line of transit traverse extending around the quadrangle and another across the center in an east-west direction it is possible to reconstruct the land net with the accuracy demanded by the usual field-map scales, even if the surveyor's chain used in the original survey was not true in length. In this case a correction is obtained for the particular chain used by the surveyor, by comparing true distances between transit-traverse points with corresponding distances as measured with the chain. For this comparison it is permissible to use scaled distances between carefully plotted transit-traverse points, so that it is possible to make numerous determinations of this correction, both in north-south and in east-west directions. The photographs can then be adjusted to the net of section lines, because known points are available at each section and quarter-section cor-

ner, and the desired data can be reduced by the pantograph or by photography and transferred to this net. This method should always be used wherever it is possible to obtain a good adjustment of the public-land net.

It may be found impossible to reconcile the distances given by the photographs with those of the adjusted land lines. This indicates that the adjustment is at fault, either locally or as a whole. It is often possible to obtain a better adjustment by disregarding the notes of the original survey and reconstructing the net wholly from data taken from the photographs. This method is slow and should be undertaken only when absolutely necessary, for it calls for a very close analysis of all the data available to the map compiler. The errors that were bound to creep into the notes of old surveys, because the azimuths of the lines were determined by magnetic compass, are often clearly indicated in aerial photographs by slight bends in the lines that the surveyor intended to be straight. These slight deviations in azimuth can be detected and measured on the photographs with a fair degree of accuracy.

In order to reconstruct the net of section lines from the photographs, it is advisable to lay down the meridional lines first. These lines are more likely to be straight than east-west lines, and they have the great advantage that they can be traced between transit-traverse points on a single set of north-south overlapping photographs. The overlap is very valuable in detecting bends in the section line that is being traced. Should a section line be followed in this way and found to be straight, it can be drawn on the map with confidence, for it is manifestly impossible for a topographer working on a field scale of 1:48,000 to detect deviations that the map compiler can not find on photographs having a scale of 1:12,000. The section corners can be tentatively plotted along such lines by applying the accepted correction to the chained distances as given in the field notes of the original survey. The photographs should then be carefully examined in order to find any east-west lines that are straight between transit-traverse stations. These are more difficult to find than north-south lines, for in general they are bent, many of them are offset on the range lines, and they are difficult to handle because it is necessary to use photographs from many different flights, between which there is not usually a large overlap.

A well-constructed index map is a great help in this work, as it will show the photographs that are adjacent in a lateral direction and enable the map compiler to follow rapidly the section line that he is investigating. As the later overlap is usually very small it is of no help in detecting bends in a line. Fortunately, such bends are generally found at section or quarter-section corners, and a test with a straightedge will determine whether the line is

straight through such points. Such east-west lines as are found by this test to be straight throughout are then added to the map, and their intersections with the straight north-south lines previously placed on the map are carefully marked as the most probable locations of these corners. If such located corners do not agree in position with those obtained by applying a correction to the chained distances, the latter should be abandoned. The north-south lines in which bends occur can now be handled more easily. Such lines should be reconstructed on tracing paper to the map scale, the angular value of the bends being obtained from the photographs. These lines when transferred to the map sheet will give other well-located section corners at points where intersections are obtained with lines previously fixed in position. The remaining corners can usually be located by the corrected chained distances, such locations always being checked by the photographs.

When other methods fail to give satisfactory location of corners on east-west lines, they may be fairly well located by data obtained from the photographs, if the line is controlled at both ends by transit-traverse points. This can be done by reconstructing the line on tracing paper and adjusting it between the transit-traverse points on the map. To obtain the most probable azimuth for each section of the east-west line a tracing is made of the north-south lines that have previously been fixed in position on the map, and to this as a base the east-west lines from the photographs are added, the mean azimuth of each section being used as the best value. These north-south lines are numbered in order from west to east. The mean bearing of each east-west line should be used, for it will be found that the azimuths of such lines, 1 mile in length, are not always the same when determined from each end. These mean bearings can be determined graphically, as follows: Place the tracing of the north-south section lines so that the line passing through the fixed control point on the west side is superimposed on the corresponding line on the photograph. Copy the east-west line desired and mark the point where it cuts the north-south section line No. 2. Adjust the tracing in such a manner that line No. 2 is superimposed on its image on the next photograph to the east, and the same east-west line passes through the primary point on line No. 1. Mark the point where line No. 2 is cut by this east-west line. If this point differs from the position obtained previously, use a point midway between them as the true position for this corner. Continue the location of corners across the entire sheet in this manner, until the transit-traverse point on the east side has been located. The section line shown on the tracing can then be transferred to the map.

The adjustment of the details that make up the body of a map compiled from single-lens photographs is not difficult if the lines



representing the public-land system have been accurately adjusted. If the amount of detail to be taken from the photographs is not large, it will probably be best to pantograph the strip mosaics on tracing paper and adjust them to the section lines as plotted on the final map sheet. It has been found that better copy is obtained from the pantograph if a steel stylus is substituted for the usual pencil reproducing point. This stylus should have a thin conical point, slightly rounded on the end so that it will not tear the carbon paper over which it will work. The tracing paper on which the reproduction is to be made is fastened to the drawing table in such manner that it is possible to slide a sheet of carbon paper beneath it. The carbon surface should be upward, so that the movement of the steel point over the tracing paper will cause the drawing to be reproduced on its lower surface. The particular advantage of this method of operation is that an extremely fine, even line is obtained and that by using carbon paper of different colors, the drainage, culture, and woodland features can be shown separately, thus making the drawing more legible. Added advantages are that the steel point rarely needs sharpening and the drawing may be transferred to the map sheet readily by rubbing with a burnisher.

It will generally be found that all such pantographed detail will require some adjustment to fit the control scheme, owing to the fact that any photograph may not have a constant scale throughout, as has been explained elsewhere in this chapter. This variation in scale is due to inclination of the photographic plate at the moment of exposure and will generally be exhibited as a contraction in size of image on one side of the line of flight and an enlargement on the other side.

In mapping areas of great detail it may be advisable to ink on the face of the photograph the detail that is to be shown on the map, using a waterproof black ink. The photographic image can then be bleached out, leaving only the inked lines on a white surface. This line drawing can then be reduced photographically to the desired map scale and adjusted to the correct position on the map.

#### RADIAL-LINE METHOD

The radial-line method of compiling a map from aerial photographs is practically restricted to the multiple-lens type of photograph, because the lines available for orientation on single-lens photographs are not sufficiently long to give the best results. This objection to the use of single-lens photographs largely disappears when the map scale is very large or when great difficulty is encountered in joining the prints by image points owing to displace-



ments caused by the relief of the terrain or tilting of the aerial camera.

On account of the extremely large angle of view utilized in the multiple-lens camera, slight tilts of the airplane or small differences of elevation of the ground surface have very pronounced effects on the photographic image near the outer limits of the angle of view. With ordinary good flying by the pilot, and only small differences of elevation on the ground surface, these effects do not greatly increase the difficulty of utilizing the photographs for small-scale maps. The comparatively large displacements at the edges of the multiple-lens photographs are very valuable in indicating the amount of the displacement due to tilt that exists near the center of the photograph. In the ordinary single-lens photographs the angle of view is so small that it may be impossible to determine whether the photograph is undistorted or not, for the distortions, if present, are not readily apparent to the eye. In using the multiple-lens photographs, however, it can be safely assumed that if known parallel lines or right angles near the edge of the field of view are shown as such in the photograph, then the image near the center must be free from distortion caused by tilting of the airplane, and will have a constant scale throughout.

The principle utilized in the radial-line method of compiling a map from tri-lens photographs is that if from any unknown point the two angles to three instrumentally determined points are observed, then it is possible to compute the location of the unknown point and the azimuth of any or all three of the unknown lines. This is the three-point problem, familiar to all triangulators. If the two observed angles are carefully plotted on tracing paper, it is possible to shift the tracing until the three radial lines pass through the three corresponding known points, as plotted to scale on the drawing. The unknown station, which is represented by the point from which the radial lines diverge, is then located correctly with regard to the known stations. This graphic method of solving the three-point problem is known to all topographers and is commonly called the tracing-paper solution. It has the advantage that all the known points visible to the topographer can be utilized in solving the problem.

The best determinations of position and orientation are obtained by this method if the angles are large and the distances to known points are comparatively great. The tri-lens or four-lens type of photograph is superior to the single-lens type both in size of angle and in length of line available for orientation, and for this reason the single-lens type will not be considered in describing this method.

Multiple-lens photographs that will enable the map compiler to distinguish houses and other fine detail with reasonable certainty

should have a scale of 1:20,000 or slightly larger. Compiling the map to approximately the mean scale of the photographs has the advantage that many of the data desired can be transferred directly from the photographs to the map with only slight adjustments in position. However, a map of a 15-minute quadrangle on a scale of 1:20,000 is large and hard to handle, and, if practicable, it should be compiled in quarter-sheet sections—that is, in  $7\frac{1}{2}$ -minute sheets. The disposition of the control points over the area plays an important part in determining the size of the sections to be compiled as separate units.

The greatest speed in compilation will be attained in this type of work by compiling these units on tracing cloth or celluloid sheets. After determining an appropriate scale for the photographs covering a quadrangle, a polyconic projection should be made to that scale on celluloid or tracing cloth and the primary control plotted thereon. Each control point should then be carefully located and marked on the photographs by a small dot of red ink. To insure accurate positions and orientation of the photographs in a strip it is essential that one of these control points be located well to the outer edge of each A and C picture and a third point close to the center of the line of flight. This set of three control points must appear on two overlapping photographs. Careful inspection of the photographs should be made to determine where this condition is best fulfilled, and the compilation should be started at that point, for its accuracy is largely dependent on the correct disposition of these starting points. On the first photograph draw a short radial line in black ink or Chinese white through each control point from either the principal or the nadir point of that photograph. The principal point may be defined as the intersection of the optical axis of the camera lens with the plane of the photographic negative, and the nadir point as the representation on the negative of the ground point vertically below the camera at the moment of exposure. As the separation of the principal and nadir points on any photograph is due to the inclination of the camera that existed when the photograph was made, it follows that these points will coincide whenever the exposure is made with the lens axis in the vertical position.

In addition to the lines through each control point draw other short radial lines through other definite points that it is desired to locate carefully. These tertiary points, if they may be so termed, should be well distributed over the photograph, always including some to each side and along the forward edge. One tertiary point should always be chosen as close as possible to the radial line drawn in the direction of the center of the next photograph. If possible, identify on the first photograph the nadir point of the second photo-

graph and draw a radial line through this point. With these radial lines drawn in ink on the photograph it is ready for use. Place the tracing cloth on which the control points have been plotted over this photograph and shift it until each plotted point falls on the corresponding radial line on the photograph. The photograph is then in correct orientation, and the nadir point or the principal point, as the case may be, is correctly located. Mark the position of the nadir point on the tracing with the number of the photograph for identification. From the point representing the nadir point trace the radial lines to the tertiary points previously selected on the photograph and to the point representing the nadir point on the next photograph. This photograph may then be removed from under the tracing. Prepare the second photograph by drawing short radial lines from the nadir point or principal point to the control points previously identified on the first photograph and to all tertiary points that are to be located, including all the tertiary points that coincide with those selected on the first photograph and any new ones on the forward edge of the second photograph. Draw also a radial line to the point representing the nadir point of the third photograph if it can be identified. The second photograph can then be placed under the tracing and oriented by causing the plotted control points to fall on the corresponding radial lines, as was done for the first photograph. This adjustment should be carefully inspected to see that the radial line traced from the nadir point of the first photograph to the point representing the nadir point of the second photograph actually falls over the nadir point of the second photograph. If this condition is satisfied, the photograph is probably well oriented, and its nadir point can be marked and numbered on the tracing. The radial lines to the tertiary points should then be carefully copied on the tracing. It will be found that the radials to a tertiary point drawn from the nadir points of the first and second photographs will intersect, but at a point that probably does not coincide with the image of the point on either photograph. This intersection, however, should be the true position of the point, regardless of any distortions existing in the photographs, if the angles of intersection are not too acute and the nadir points of the photographs are exactly known.

The third photograph is handled in the same manner as the first and second with the exception that the three original control points will not appear on it. Points located by good intersections must be used for orientation of this and succeeding photographs, until a photograph made where the flight again crossed a control line is reached. Points on this control line are then intersected on the tracing in the same manner as other tertiary points, and this operation is a check on the accuracy of the position carried forward by



the photographs. The closure of this line on fixed points near the line of flight will probably indicate a small error in distance and a very small one in azimuth. If this error is very small it can be neglected in view of the large reduction to which the drawing is subjected before reaching the topographer, but if it is too large to be neglected the work should be repeated until the closure is satisfactory. The intersected points falling in the outer portions of the wing pictures may be expected to be out of position laterally, owing to the acuteness of the angles of intersection. They serve to orient the photographs, however, and the location of each is strong in the general direction of the radial lines, but their preliminary positions must be used with care in the final compilation.

In flying over a quadrangle to obtain multiple-lens photographs for use in mapping, the pilot will often either purposely or accidentally overlap one flight a considerable amount on another. This overlap is of great help to the map compiler, as it strengthens his work by eliminating the most acute intersections near the outer ends of the photographs, and moreover, it gives him many common ties between the two flights which will necessarily bind them together more rigidly than if the two flights overlapped but a small amount. Probably the strongest combination is obtained by overlapping the flights more than 50 per cent. This will result in a series of photographs showing on their outer wings about half of the area photographed on the central part of each photograph in the adjacent flights. Points along the center of a photographic flight are more accurately located than points shown elsewhere on the photographs, and if they appear on the wing pictures of the adjacent flight they can be used as points of control for that flight.

To make the best use of this method it will be necessary to build up the tertiary control net from the two or more overlapping flights simultaneously, assembling three pictures made in the first flight, then three in the second, three in the third, and so on as far as the large overlap extends. Intersections from other photographs in these flights can be built up gradually in the same manner, using a few photographs from each flight at a time. To work most rapidly by this method and to insure the use of the same points in the overlapping region, it is well to select and mark the points that will be used before undertaking the work of intersection. If difficulty is experienced in identifying the points readily, they may be numbered. The nadir point is more accurately located than other points of a photograph; consequently it should be identified on the wing pictures of the adjacent flights, if possible, and used as a fixed point in the control net.

The accuracy of acute intersections such as occur on the wing prints or tri-lens photographs is greatly increased when four-lens



photographs are used, for these acutely intersecting lines may be strengthened by an additional line from the D photograph of the adjacent flight, provided that a normal lateral overlap of flights has been attained. This strengthens the entire compilation so much that rotation of the camera in its mounting in order to increase the angle of intersection on the wings, the usual practice with a tri-lens camera, is unnecessary.

If the scale of the projection has been carefully chosen to fit that of the photographs, it will be found that the tertiary intersected points that correspond to points near the center of the photographs agree very closely, but that those toward the outer edges will diverge. In flat country this discrepancy will be due to tilt of the airplane at the moment of exposure and will generally be exhibited as a reduction in scale on one side of the line of flight and a corresponding enlargement on the other side; in mountainous country it will be due to a combination of the displacements caused by tilt and by the relief of the terrain. The effect of this combination of two distortions of the image may be puzzling at times, for it is possible for the tilt to neutralize the effect of the relief on one side of the line of flight while increasing it on the other side. These two distortions occur in all aerial photographs, and their relations are so involved that they can be separated only by reprojecting the negative and eliminating the effect of the tilt. This procedure requires a knowledge of the elevation of ground points and special equipment for measuring the coordinates of these points on the negatives, and at present it is not practicable for small-scale mapping.

It is good practice to select road corners or bends in roads as tertiary points for intersection, as they serve the double purpose of controlling the map and building up the road net at the same time. If the road corners have been or can be located on the tracing by intersection, it will be an easy matter to build up the entire road net by simple inspection of the photographs if the roads are straight lines or by adjusting the intersected points over corresponding points on the photograph and tracing the roads directly if they are irregular.

After the roads have been satisfactorily located on the tracing it is well to introduce many of the more important fence lines. These also will serve a double purpose, for in addition to being helpful to the topographer in the field they break the area of the map into small units that are of great assistance in transferring details from the photographs to the base tracing. As many fence lines should be added as will be needed to limit the size of the inclosed parcels to 2 or 3 square inches on the map. Near the outer edges of the photographs these parcels may well be smaller, as the distortions are larger in this region and there is consequently more need for ad-

justment of the details. In sectionized country the correct positions of the fence lines are easily obtained, as each fence can generally be located by drawing a single radial line to the point where the fence intersects a road. As the road has previously been located, a single line cutting it at a good angle gives the true intersection. In the Eastern States, where property lines are irregular, it is difficult to locate the fences correctly, as the relief introduces apparent bends into them that are hard to distinguish from the real bends. Theoretically it is possible to locate these fences correctly by intersecting points along them at close intervals, but as the fence lines are not shown on the published map the result is not worth the time involved. Many fences are shown on the photographic base map, as they furnish some information concerning the country away from the roads, but it should be recognized that they are not located with the same care as roads. For this reason the topographer should not infer that his stadia traverse is in error should he fail to close on a fence line by a small amount. In wooded country that is being surveyed by means of a tape and aneroid barometer it is probably advisable to accept these fence lines as they are shown, for it is known that no very large errors of position exist in them.

When the area has thus been broken up into small parcels, the road and fence lines should be inked on the tracing in fairly heavy black lines. It is advisable to use only a single line for a road, as better positions can be obtained for houses adjacent to the road by so doing. The tracing should then be adjusted over the photographs and the details traced wherever the parcels have the same size and shape on both tracing and photograph. If the discrepancy between the tracing and photograph is small the detail on the photograph can be adjusted to an approximate position without difficulty. If the photograph is badly distorted it may be necessary to determine additional points on the tracing by intersection, thus further breaking up the area into parcels small enough to adjust with reasonable accuracy. As all portions of the area appear on at least two photographs it will often be found that an area badly distorted on one photograph is well represented on the adjoining photograph. In taking detail from the photographs the map compiler will find that he can distinguish and show with reasonable certainty houses, large buildings, minor roads and trails of sufficient importance to aid the topographer, railways, cemeteries, bridges, overhead and below-grade crossings, fences, and crop boundaries, grant lines, section lines and other civil boundaries, woodland areas, streams and water bodies, such as lakes, ponds, marshes, and small depressions holding water only during the rainy season. Familiarity with aerial photographs enables the compiler to distinguish

usually between houses, barns, and schoolhouses, and in certain areas topographic features, such as cut banks and depressions, may be identified.

After all such detail has been traced it should be inked in black, using bold lines throughout. No time should be devoted to neat drafting, as this compilation is intended only as a guide to the topographer, and accuracy of position is the prime consideration. The photographic reduction to which this inked copy will be subjected before it reaches the topographer will sharpen it up, and if made too fine some of the detail might disappear in the process of reduction. It is generally advisable to give the exact outline of woodland areas and to indicate by means of the letter W or by the customary zigzag line that the area is wooded. Where details have been shown but not positively identified, an interrogation mark should be added to draw the topographer's attention to the fact that they may need correction. Features that are discernible but not identifiable should be outlined and questioned in the same manner.

The position of the center of each photograph and its number should be marked on the tracing in blue ink, which will preserve it on the original but will not reproduce on the field sheet. The points of control should be inked in black and marked in a distinctive manner so that the topographer can recognize them. The name of the quadrangle should be inked along the north edge of the drawing, and the quadrangle name, the file numbers of the photographs used, the scale of the projection, and the draftsman's name should be placed in the margin below the southwest corner.

The drawing is then ready for reproduction, and as it is on a medium greatly subject to uneven expansion and contraction, the usual graphic reduction scale should not be used, but the meridional distance desired in the reduced map should be given to the photographer. In this way the reduced drawing will be to the desired scale along the meridians but will probably be off scale a small amount in the east-west direction, on account of uneven expansion or contraction of the tracing cloth. This will not affect the accuracy of the field work and can be eliminated in reproducing the map for publication.

Photolithographic prints in nonphotographic blue are made on double-mounted paper, and additional prints in black are made on map paper. The black-line prints are made as office records and for the convenience of the topographer, as they are more legible than the blue-line prints. They provide a base on which may be shown information collected but not placed on the field sheet. Plate 29 shows one of these sheets as it goes to the topographer.



## MOSAICS

For the interpretation of certain features of the terrain photographs are so much more valuable than maps that it may be advisable at times to assemble the photographs as a composite picture, rather than use them for map construction. Such composite pictures are called mosaics. They may be either controlled or uncontrolled.

Controlled mosaics may be used in map construction under some conditions, but their usefulness is generally restricted to the commercial field to meet demands for local detail in city planning, laying out power lines, and other projects of similar nature. For this reason their construction is described only briefly.

The fact that a mosaic will not be accurate in scale should not be overlooked. The type of topography, the character of the flying accomplished by the pilot, and the skill of the mosaic builder all have their effect on the scale of the compilation.

For uses in which accurate scale is not important and the relative position of local details alone is needed an uncontrolled mosaic may be used to advantage. In a mosaic of this type the photographs used in the compilations are tied together only by their images, and consequently any displacement of the image existing in the photographs, due either to tilt or to relief, will have its disturbing effect on relative positions and scale. The best mosaics of this type will be obtained where the terrain has but slight relief. Multiple-lens photographs are not satisfactory for mosaic construction, as even slight tilts distort the images on the wing pictures severely.

An uncontrolled mosaic may be built around a single photograph as a nucleus or it may be built laterally from a single flight accepted as a base flight. In building around a single photograph the prints are fitted together as accurately as possible by matching images, and when satisfactory junctions have been obtained they should be pasted down on compo board or some other firm mounting surface. In pasting the prints to the mounting board overlapping should be kept at a minimum, as it will increase the thickness of the mosaic in such portions and consequently increase the difficulty of obtaining an even illumination over the surface when it is copied photographically. Evenness of illumination is greatly improved by beveling the overlapping edges. Prints that do not match in scale the one that has been already fixed to the mounting board can be enlarged or reduced to fit. Such changes in the prints should be avoided if possible, however, for they can easily be the cause of much trouble if the photographs are distorted and not merely off scale. Any correction applied to a print that is off scale but not distorted will affect the entire print equally; but if an enlargement should be



applied to a tilted photograph to make its contracted edge join another print, it will be found that the enlarged edge of the tilted photograph has been still further enlarged and the error on that side increased. In regions where the relief is sufficient to distort the images appreciably the photographs should be taken with very large overlaps and only the middle portions used in making the mosaic. This procedure reduces the effect of the distortion but does not eliminate it, and some difficulty is bound to occur in matching the prints. Moreover, the areas that stand above the accepted datum plane are bound to have a larger scale than the rest, and nothing that can be done to the prints will alter that fact.

A mosaic compiled around a single photograph, as just described, will have as a scale the scale of the nucleus photograph if the matching was well done. Some other scale can be obtained in copying if the distance between two positively identifiable points on the mosaic is known, or it can be obtained in the original mosaic by photographing the nucleus print to the desired scale, and reducing or enlarging all other prints sufficiently to match it.

More accurate determinations of position can be obtained in an uncontrolled mosaic by building laterally from the photographs of a single flight laid down by the straight-line method of orienting prints, already described. This procedure gives a more rigid "backbone" upon which to adjust the prints than a single print used as a nucleus. •

Controlled mosaics are more accurate in scale and position than uncontrolled mosaics but are more difficult to construct. Well-run transit lines furnish satisfactory control when points visible on the aerial photographs have been located by the traverseman, and records of local engineering offices can often furnish data of value for this purpose. Triangulation is probably the least satisfactory of all forms of control for mosaic construction, as the stations are usually few and very difficult to identify on the photographs. An approximate form of control can be obtained by enlargement of an existing map, although this method has the great disadvantage that any error in the map will be magnified in bringing it up to the scale of the mosaic.

If transit traverse is used to furnish control with the usual north-south direction of flying, it will generally be possible to find a control point at each end of a flight. The straight-line method makes possible good orientation of the photographs between these points, and by plotting the centers of the photographs in correct position with regard to the straight line the photographs are prevented from getting far out of position. The photographs of each flight that permits it should be tied down in the same manner. Advantage should be taken of any straight lines appearing on the

strips laid down fitted to control by extending them as far as they appear on the photographs and holding the mosaic to them. Where control points are isolated the problem is more difficult, for it is necessary to build up straight-line control between each isolated point and the fixed strips already laid down. If the straight-line method is not used for this purpose, difficulty will always be experienced in obtaining the correct orientation and position for the photograph on which the isolated control point falls. The photographs of the mosaic that are not on lines connecting control points must be added by matching prints as in the uncontrolled mosaic.

The mosaic may be used in its original form or may be reproduced by photography in single sheets or in sections depending on its size and upon available photographic equipment. The reproduction can be made to any convenient scale.



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